NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

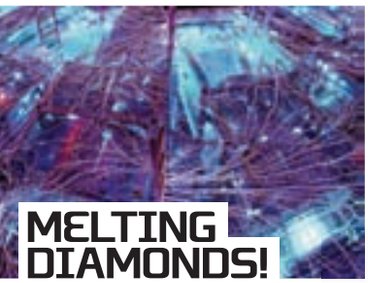
SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

INTERVIEW

SIR JAMES DYSON

On his revolutionary new invention



MELTING DIAMONDS!

How the incredible Z machine generates 290 trillion watts

NORTHERN LIGHTS

Nature's most amazing light show explained

LION LIFE

Discover how a pride of lions live, hunts and survives

THE REAL CSI

Find out how modern science can help catch and convict criminals

ROBOTS

Real-life androids that fight wars and save lives

916 FACTS AND ANSWERS INSIDE

HOW THE PYRAMIDS WERE BUILT

Secret of the world's most awesome monuments explained

CAN WE LIVE ON MARS?

REVEALED! NASA'S PLAN FOR A MANNED MISSION TO THE RED PLANET

+LEARN ABOUT...

- SUPERNOVA
- V-2 ROCKET
- RAILGUNS
- BLUETOOTH
- ECO HOMES
- AIRBUS A380
- JETPACKS
- GLACIERS
- ADDICTION
- GEARBOXES
- BIOFUELS
- M1 TANK

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ip IMAGINE PUBLISHING

HOW IT WORKS

WELCOME

The magazine that feeds minds! ISSUE TWO

Get in touch

Have YOU got a question you want answered by the How It Works website? Get in touch by...

Email: howitworks@imagine-publishing.co.uk
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Snail mail: How It Works
Imagine Publishing, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

"FEED YOUR MIND!"

The sections explained

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The natural world explained

SCIENCE
Explaining the applications of science in the contemporary world

HISTORY
Questions answered on how things worked in the past

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

TRANSPORT
Be it road, rail, air or sea you'll find out about it here

SPACE
From exploration to the solar system to deep space

Meet the experts

Here's a selection of the experts that helped make **How It Works** a reality this month, each of them eager to feed your mind with knowledge

Helen Laidlaw
Deputy Editor

The newest member of the How It Works team joined just in time to help issue two off to the printers. Helen joins us from games™ magazine so it's not surprising that her favourite gadget is her Nintendo DS.

April Madden
Eco-homes

April takes a very keen interest in all things ecological and environment based. Researching the excellent article on eco-homes (page 22) gave her a change from her day job of writing for Digital Artist magazine.

John Brandon
Can we live on Mars?

John is our resident space nut. We say resident, he actually lives some 4,031 miles away from the office in Fergus Falls, Minnesota. It's a small distance in comparison to Mars, the subject of his feature on page 64.

Dave Roos
The real CSI

Dave wrote our feature on CSI, he isn't a CSI himself. He's a freelance writer and part-time farmer who recently returned to the US. He lives in Pittsburgh which is 3,673 miles away from the How It Works office.

Shanna Freeman
Pyramids

Shanna can write about many things but this issue we chose to turn her admirable research skills to a feature on the construction of the Egyptian pyramids. Enjoy the fruits of her labour on page 74.

With thanks to

How It Works would like to thank the following companies and organisations for their help in creating this issue

dyson GARMIN sciencemuseum NASA DK REUTERS

Welcome to the second issue of How It Works, the magazine that's driven by our enthusiasm and passion for all things science and technology related. It's a passion that seems to be shared by many others judging by the reaction to our first issue, which had a great reception from the public and press alike. Almost everyone who contacted us was impressed with the amount of information that we managed to pack into the pages along with the cutaway images and plentiful diagrams.

Trumpet blowing aside, we've been working even harder to maintain the high standard we set in our first issue. This time How It Works covers an equally broad spectrum of fascinating facts that takes in lions, robots and Mars, a look at an alternative theory to how the pyramids of Egypt were built and a peek under the armoured exterior of an M1 tank. If that doesn't whet your appetite for knowledge try our look at real-life crime scene investigators and the differences between their daily lives and a certain TV show. Or eco-homes, or jetpacks, or the Airbus A380, or V-2 rockets, or biofuels, or Maglev trains, or hydroelectric power or... you get the idea, now go FEED YOUR MIND!

Dave Harfield
Editor in Chief

Editor's pick

The Abrams M1 tank is my favourite article this issue. Partly because I live in the same county as the great Bovington Tank Museum but primarily because of the great cutaway illustration from leading cutaway artist Alex Pang. It's on page 40.

What you're saying about How It Works

Great magazine – I was really enjoying reading it until my young son pinched my copy and is now devouring the information in it! – **Philsy, forum**

It is a prime example of why printed magazines will remain dominant for some time to come and I for one will be subscribing – **Shaun McGill**

HOW IT WORKS

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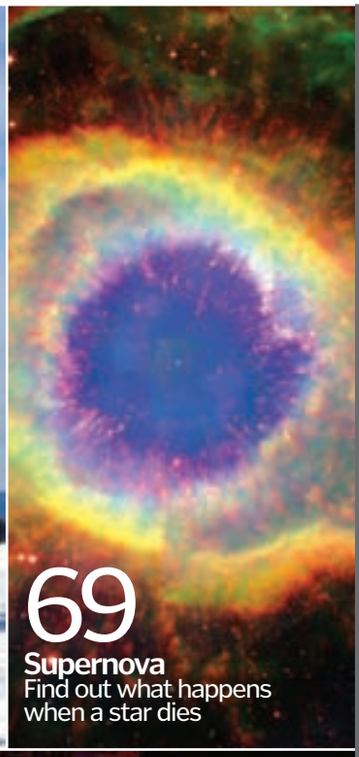

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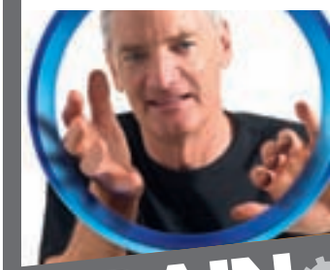


BRAIN DUMP
Because enquiring minds want to know...

Alison Boyle
Curator of Astronomy
Alison joins us this issue to answer all our space questions

Rob Skitmore
Assistant Curator of Technology
Rob tackles all queries related to technology

Phil Raby
In-house expert and Editor in Chief of Total 911
Our transport guru has the all the answers

THE HOW IT WORKS KNOWLEDGE
For connoisseurs of kit and savants of stuff

Images © ESA

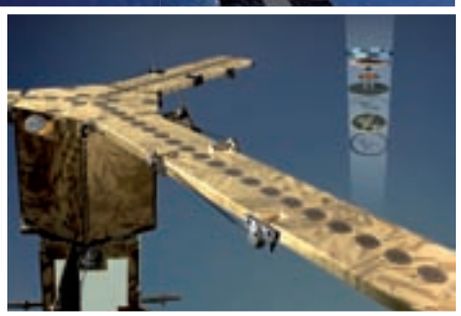
A close eye on climate change

Europe launches satellite to monitor Earth's water cycle

While concern for the planet's future grows, the European Space Agency has launched a second mission in its Living Planet Programme to collect data that will better enable scientists to understand the way water moves around the Earth.

The Soil Moisture and Ocean Salinity (SMOS) mission involves sending a satellite into orbit to observe soil moisture over the surface of the planet as well as the salinity of the oceans. SMOS will detect variations in the water below by capturing images that show changes in the emission of microwaves from the Earth's surface.

SMOS successfully launched from Russia on 2 November, and once the satellite was in position, a Y-shaped radiometer measuring eight metres across was deployed. Each arm of the radiometer carries arrays of antennas, enabling the unit to detect far more information than just a single receiver ever could.



On board SMOS is the Microwave Imaging Radiometer using Aperture Synthesis, or MIRAS. A radiometer is a device for measuring electromagnetic radiation, and with its Y-shaped configuration, MIRAS has three deployable arms, each consisting of three segments. 69 antenna receivers cover the blades of this helicopter-shaped structure. The above image shows a detailed view of an antenna.

With the new information gathered and sent back to Earth by SMOS, weather forecasting will be much improved and the advantage of this means we will have a much clearer picture of what the climate is going to do over the coming years. A very worthy space mission, and it all started here in Europe.

NASA's Ares X-1 flight test success

One giant leap closer to putting man back on the moon

The Ares X-1, a test rocket for NASA's newest manned space exploration programme, successfully lifted off from Cape Canaveral's Kennedy Space Center at 11:30 EDT on 28 October.

The six-minute flight, which saw the prototype reach Mach 4.75 (nearly five times the speed of sound), enabled NASA to test hardware and collect data – including aerodynamic measurements and control details – essential to the development of the next generation of space flight. NASA intends for the Ares X-1 to take over from the ageing Space Shuttle vehicles as a new method of transporting humans beyond low Earth orbit. A NASA spokesperson has said: "This is a huge step forward for NASA's exploration goals."

The launch itself may have gone without a hitch, but the booster rocket was damaged upon its return to Earth. It crash-landed into the Atlantic Ocean due to the deflation of one of the landing parachutes. The severely dented first stage booster was recovered from the ocean before being sent back for analysis.

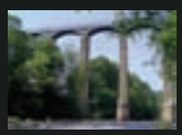
Although the test flight remains a success, a panel asked by President Barrack Obama to review the entire programme has questioned the massive cost and the long development time of the project during the current recession. The American leader is due to issue a response over the coming weeks.

While the venture clearly faces opposition from other parties, there's always the chance that the recent discovery of water on the moon could spark a 21st Century space race the likes of which has not been seen since the Soviet Union and the United States of America sparred for space supremacy back in the Sixties.

This day in history

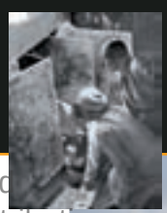
26 November: Major events that occurred on the same date this magazine hit the shops

1703 Ravaging the south of England, the Great Storm of 1703 is at its most destructive on 26 November. The unprecedented weather leaves around 8,000 dead.



1805 126 feet over the River Dee, the Pontcysyllte Aqueduct opens to the public.

1922 Archaeologists Howard Carter and Lord Carnarvon become the first people to enter Tutankhamun's tomb for around 3,000 years.



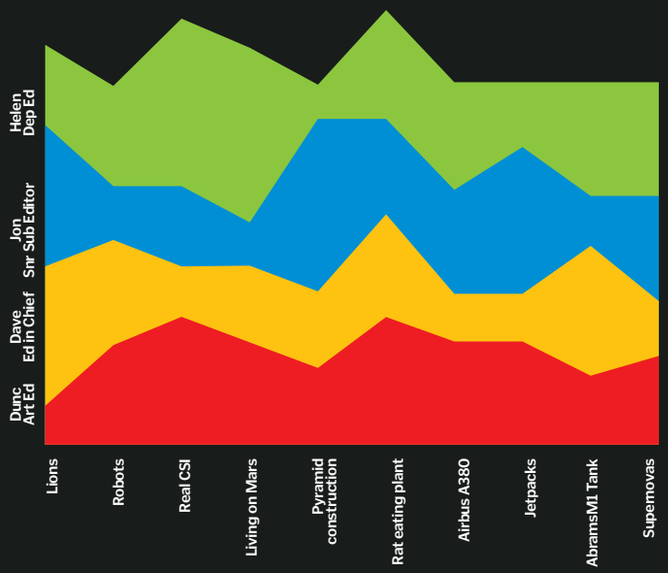
1941 Franklin D Roosevelt signs a bill officially marking the fourth Thursday in November a national holiday of Thanksgiving in America.

1965 The French launched the Diamant satellite into space, making it the third nation to do so after the Soviet Union and the United States of America.

Images courtesy of NASA

HOW IT WORKS EXCITE-O-METER!

Every issue we offer this visual guide to what's been getting us excited in this issue of **How It Works**



It turns out the art editor and editor in chief were the most excited this month with an equal excitement rating of 76 per cent. We expected a bit more from new recruit Helen Laidlaw though, who was level pegging with senior sub editor Jon White on 72 per cent. Dave, a vegetarian, was most excited about the rat-eating plant, though he has moral reservations about the picture on page 18 claiming that "someone's dropped the rat in there". Hippy.

A poll set up by the Science Museum reveals that the public thinks the X-ray machine had the biggest effect on future science

X-ray is the greatest invention of the century

To commemorate 100 years of "making sense of science", London's Science Museum opened a public vote to determine our favourite scientific inventions.

A list of ten inventions from the last century was drawn and more than 50,000 of us voted, with results confirming that the things we are most fascinated by are inventions that enable us to discover 'how things work', specifically with regard to our bodies. The top three Centenary Icons were all based on medical advances, with the x-ray machine topping the poll.

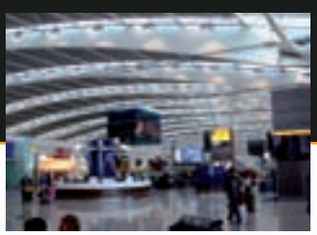
According to Ben Bradshaw MP, Secretary of State for Culture, Media & Sport: "The public's choice of the x-ray machine as the winner of this poll is testament to our insatiable curiosity to find out how things work."

In 1895, the invention of the x-ray machine heralded a fascinating future for doctors who could now see inside the body, enabling them to diagnose illness without surgery. The Reynolds x-ray machine on show at the Science Museum was constructed by a father and his son who were inspired by the discovery of the x-ray.

THE RESULTS

1st: X-ray Machine – 9,581 votes
2nd: Penicillin – 6,825 votes
3rd: DNA Double Helix – 6,725 votes
4th: Apollo 10 Capsule – 4,649 votes
5th: V-2 Rocket Engine – 3,985 votes
6th: Stephenson's Rocket – 3,533 votes
7th: Pilot ACE Computer – 3,472 votes
8th: Steam Engine – 3,457 votes
9th: Model T Ford – 3,231 votes
10th: Electric Telegraph – 2,694 votes

1983 Gunmen disguised as guards overcome security staff at Heathrow airport and make off with £25 million worth of gold bullion.



1991 American aircraft designer Ed Heinemann dies. Heinemann oversaw the development of the F-16 single-seat fighter plane.

1992 Queen Elizabeth II becomes the first monarch to pay income tax since the Thirties. Her Majesty's fortune is currently an estimated £275 million.

2003 Supersonic wonder Concorde takes to the air for the final time, flying from Heathrow to Filton near Bristol, where the plane made its first test flight in 1969.

2008 Over 100 people are killed in a terrorist attack on the Indian city of Mumbai. Pakistani Mohammad Ajmal Amir Qasab has since pleaded guilty for his part in the crime.

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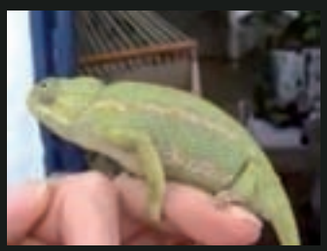
HOW IT WORKS TV

The How It Works website is regularly updated with the most amazing videos the net has to offer

Don't just blend in

■ Watch as this little reptile changes colour before your eyes. The chameleons' amazing colour change is the result of light, temperature and emotion.



Swept away

■ This home-made video of a skier caught in a sudden avalanche is a stark reminder of the threat posed by this natural phenomenon.

2009 land speed record

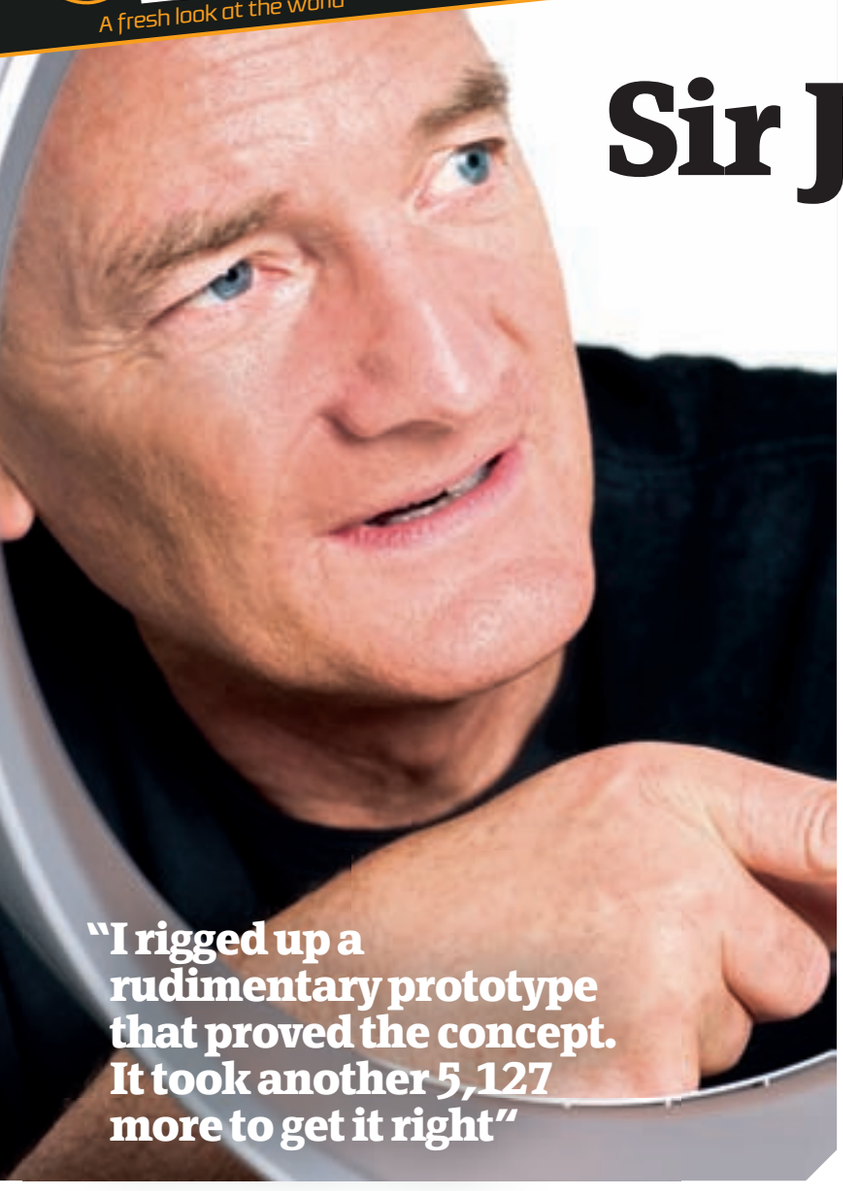
■ The petrol-powered Spectre SpeedLiner reaches a speed of 328mph, making it the world's fastest gasoline class, wheel-driven streamliner.

Killer whale vs seals

■ Look away if you're easily upset, because this National Geographic clip features incredible footage of natural hunters in action.

Sir James Dyson

Sir James Dyson is one of the most recognised British inventors of the last century and his inventions can be found in homes around the globe. But just how did he get to where he is now?



"I rigged up a rudimentary prototype that proved the concept. It took another 5,127 more to get it right"

HIW: How did you first hit upon the idea of using cyclonic separation to create a vacuum cleaner that wouldn't lose any suction?
Sir James Dyson: I was inspired by a cyclone being used in a sawmill – a 30ft cone that spun dust out of the air by centrifugal force. I wondered if the same principle could work in a vacuum cleaner. There would be no need to replace clogging vacuum bags. I rigged up a rudimentary prototype that proved the concept. It took another 5,127 more to get it right.

HIW: What was the biggest obstacle you faced when bringing the vacuum cleaner to market? How did you overcome it?
SJD: The biggest single obstacle was getting financial backing. I tried with the big manufacturers, struggling over patent rights and poor deals. Many of the multinationals I originally approached turned it down because they thought it would damage sales of vacuum cleaner bags. I ended up making it myself.

HIW: Another Dyson product that impresses us is the Airblade, a hand dryer that produces an air stream flowing at 400mph. Where did the inspiration for this come from?
SJD: We were experimenting with air knives – fast moving sheets of air forced out of an aperture. We realised we could use air knives to scrape people's hands dry quickly, rather than using evaporation which is not only very slow but also unhygienic because it heats up the dirty bathroom air.

HIW: The company's latest product, the Air Multiplier, is a bladeless fan. Can you tell us how this was developed?
SJD: The idea for the fan came out of our work on the Dyson Airblade when we noticed that surrounding air was being pulled into the airflow.

We realised that this effect could be enhanced by simply passing the air over an airfoil ramp – inducing and entraining further air into the stream. By using this technology, every litre of air that the impeller draws into the bottom of the Air Multiplier can be amplified 15 times. And because there are no blades to chop up the air, there's no turbulence.

HIW: Do you take a hand in the marketing of Dyson products or do you prefer a research and development role?
SJD: I still see myself as an engineer. I spend most of my day in the research and development centre in Malmesbury. We have various projects at different stages of development. Some of our engineers might be optimising one of our designs using CAD, others will be testing out ones using rapid prototyping. We have a lot of specialist areas: aero dynamics and acoustics, for instance. There's also a large team of engineers working on our digital motors.

HIW: What advice would you give to anyone out there who wants to turn a promising idea into a worldwide, business success story?
SJD: Try not to be put off when you encounter failure. You have to keep on going and take risks – learning from your mistakes as you go. Intellectual property is crucial to the success of any idea, so focus on coming up with something that works well, something you can patent. Get the function first and the form will follow. Finally, don't listen to experts! Don't be afraid of following your instincts.

HIW: How It Works magazine explains how everything we take for granted in the world actually works – from the light bulb to the Bugatti Veyron. What is the one thing you have no idea how it works, but you would most like to know?
SJD: I've always been fascinated by the behaviour of materials. It started with plastics when I was a design student. There's a materials library in the basement of King's College London which contains all kinds of surprising and perplexing samples. There are turbine jet-engine blades grown from a single crystal and diffusion-bonded aluminium wafers used in aerospace engineering. I've recently been captivated by the development of nanotechnology and its implications for the future of materials.

HIW: What's your favourite gadget that you currently own (and didn't invent!)?
SJD: My Moulton bicycle. It's robust, comfortable and easy to dismantle.

HIW: What's next on your gadget/technology shopping list?
SJD: I like ideas that approach a problem in a new way. I'm particularly impressed by those that come from aspiring young inventors. This year's winner of our student design award was an automatic fire extinguisher. It fits inside the kitchen tap and emits a fine spray of water on detecting a fire. Automist is still in its prototype stages, but it should become a permanent safety feature in the home.

Dyson's latest creation, the Air Multiplier

CAREER

1970 After marrying Deirdre Hindmarsh in 1968, James Dyson goes to work for Rotork Marine, who built the high-speed landing craft the Sea Truck.

1974 Forms a firm with his sister and her husband to design and make the Ballbarrow.

1979 Establishes Dyson Research Ltd. It takes him 5,127 prototypes to finally create a working vacuum cleaner.

1986 The G-Force vacuum cleaner goes on sale in Japan. Despite its high price tag it becomes a cult favourite.

1993 Back in Britain, the DC01 finally goes on sale. By 1995 it's the best-selling vacuum cleaner on the market.

2002 The Dyson Dual Cyclone goes on sale in the US. By 2005 Dyson held 20 per cent of the market share.

2005 > PRESENT Using the Ballbarrow design, the Dyson Ball is added to the company's vacuum cleaner portfolio. In 2006 the Airblade is launched, a super-fast hand dryer.

This month in **Environment**

Ever wondered how lions hunt, or the best way to survive if they decided to attack? We have all the answers for you in our four-page lead feature. We also take a look at the plant that eats rats, the formation of glaciers, eco-friendly homes and much more!

18 Giant rat-eating plant

21 Glacial formation

22 Eco-friendly living

ENVIRONMENT

The lion stands proud at the top of the food chain. Discover what makes this natural born killer the ultimate hunting machine

How lions survive

5 TOP FACTS LIONS

Different from the pack
1 Occasionally lions have cream-coloured fur. These were once thought to be a separate species but it's actually a rare genetic morph called leucism.

Not so lionhearted
2 Lions have relatively small hearts for their body size; typically about three per cent of body weight, compared with 4.3 per cent for humans.

Is that a lion or a leopard?
3 Lion cubs are born with brown rosette-like spots on their fur. This provides a better camouflage for the scrubland.

A load of pants
4 Despite the searing African heat, lions have very few sweat glands. Instead they can pant up to 200 times a minute to cool themselves down.

Eyes bigger than their bellies
5 An adult lion needs an average of 5kg of meat each day but they can gorge on up to 30kg in one meal and then not eat for up to a week.

DID YOU KNOW? *Fewer than 47,000 lions remain in the wild*

Lions have been associated with royalty, strength and courage since at least as far back as ancient Egypt. Lions are social, loud and conspicuous. Of all the animals, the lion's co-operative approach to hunting most closely matches our own and so we admire them, even as we hunt them ourselves. But lions – particularly male lions – are quite different from our idealised, anthropocentric projections. They are superb predators combining stealth, planning, speed and power. But they are also selfish, brutal, promiscuous and murderous.

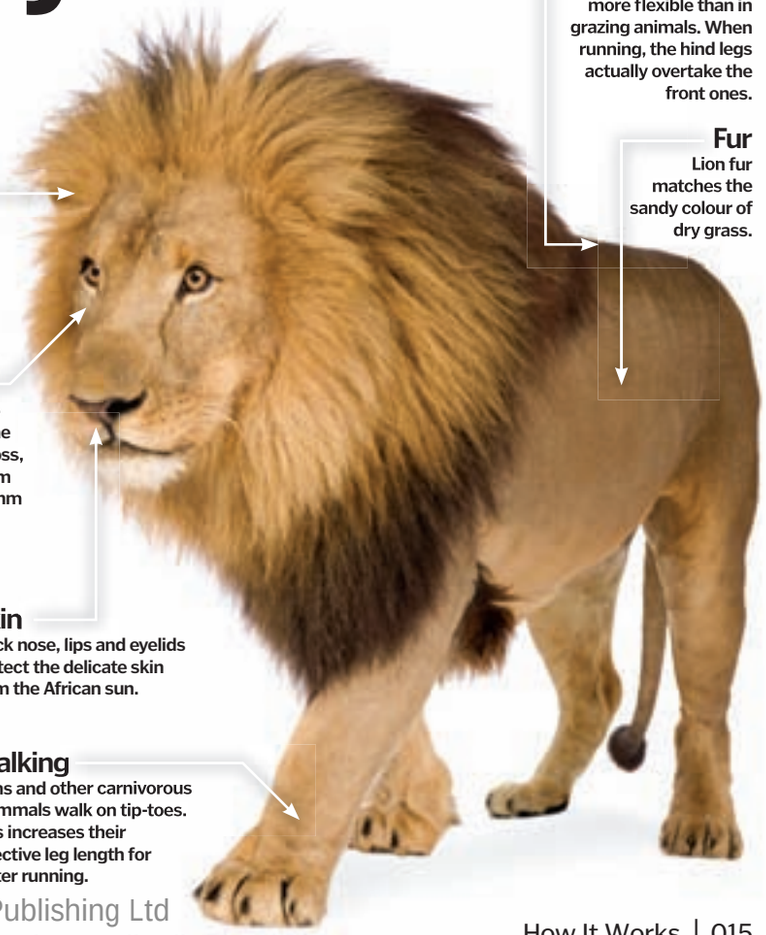
Historically, lions were found across the whole of Africa, southern Europe, the Middle East and India. Widespread habitat destruction and hunting by humans means that they are now limited to enclaves scattered across sub-Saharan Africa, mainly in designated reserves. There is also a tiny population of 350 Asiatic lions in the Gir Forest in Gujarat, India. Despite their small numbers, lions are a keystone species. This is a species that has a disproportionate influence on an ecosystem, usually by controlling the numbers of prey species. Lions serve to check the growth of herbivore herds and help to prevent overgrazing, which would otherwise cause the deserts to spread. Though their nobility is often exaggerated for poetic effect, their importance and dominance in the food chain is not.


Lions actually kill by asphyxiating their prey


Lionesses synchronise reproduction to ensure all cubs in a pride are the same age

Anatomy of a lion

Adapted for life as the apex carnivore of the savannah



Mane
The mane exaggerates the size of the male lion. This is to impress other lions; it actually makes him less effective at hunting than the females.

Eyes
Lions have very large eyes for their size. The eyeball is 35mm across, compared with 24mm for a human and 40mm for an elephant!

Skin
Black nose, lips and eyelids protect the delicate skin from the African sun.

Walking
Lions and other carnivorous mammals walk on tip-toes. This increases their effective leg length for faster running.

Spine
The spine is much more flexible than in grazing animals. When running, the hind legs actually overtake the front ones.

Fur
Lion fur matches the sandy colour of dry grass.


He's not the king of the jungle, he's a very naughty boy!

These young lions aren't too proud for some road-side dining

How lions reproduce

It's the circle of life

Lions reach sexual maturity at between three and five years. Females don't have a fixed reproductive season and when a pride has more than one male, females will mate with several partners. This may be an evolutionary strategy to keep paternity ambiguous and so reduce the likelihood of other males in the pride killing the cubs. Females are in heat for several days and will copulate between 20 and 40 times a day.

The lion penis has tiny backwards-facing spines that stimulate ovulation in the female as they drag along the vaginal walls. Pregnancy lasts 108 days and the female withdraws to a secluded den away from the pride to give birth to a litter of between two and six cubs. Lionesses synchronise reproduction within the pride so that the cubs are all the same age.


Paternity in a pride is often ambiguous

Surviving a lion attack

Lion attacks on humans are rare, but just in case...

Keep away from open ground. Lions do not like thick undergrowth with branches and thorns that they could injure themselves on. Lions are also poor climbers and are unlikely to follow you into a tree.

If you do find yourself stalked or watched by a lion, the worst thing you can do is run; all of a lion's hunting instincts are geared to expect this. But you can't run as fast as an antelope. Instead you need to turn off that predator response by acting unlike a prey animal. Face the lion, make yourself as big as possible, wave your arms and make a lot of noise. Lions hunt in groups so you may find yourself flanked, be ready for this. Wave a sleeping bag or blanket to create a false target. If it pounces, use pepper spray or hit it with a shovel. Keep shouting and back away.

Group dynamics

Lions are the most social of all cat species and generally form into prides of five or six females and one or two males. Occasionally a pride may be as large as 30 females and four males. The females in a pride are all closely related but the males never are. As soon as male lion cubs reach maturity, they are expelled from the pride. This also sometimes happens to females if the pride grows too large.

Lions that are not part of a pride are termed nomads. Male lions may change between a nomadic and resident lifestyle several times in their life but females are almost never accepted into a new pride. When a nomadic male encounters an existing pride, he may attempt to take over by fighting the dominant male. If he succeeds, he will usually kill any cubs to prevent competition for his own cubs in the future, though the female lions are sometimes able to band together and prevent this.

Within the pride, the lionesses do most of the hunting since they are faster, better camouflaged and have higher endurance. The smaller and weaker lionesses do not always join in with the hunt and instead they may stay behind in order to protect the cubs.

Males spend most of their time patrolling the boundary of the pride area to defend it against other lions. They may kill smaller prey by themselves but they won't share these kills with the pride and in fact often dominate even the larger kills that the females may bring back.

DID YOU KNOW?

Roar power

Lions have the loudest roar of any cat. They most often roar at night and can be heard an incredible eight kilometres (five miles) away.

The death of a lion

What can topple the king of the savannah?

Lions have no natural predators. As adults they normally die violently at the hands of humans or other lions. Males seldom live longer than ten years. Once they become injured or their strength declines, they are unable to defend their leadership and will be killed or driven away from the pride by other nomadic males. Females can also be killed when prides overlap in their hunting ranges. Lion cubs have a very high mortality as well. If they aren't killed by incoming males, they may be eaten by jackals, hyenas, leopards, Martial eagles or snakes. 80 per cent of cubs die before the age of two.

The lion population has declined by around 40 per cent in the last 20 years with fewer than 47,000 remaining in the wild.

Hours of planning and patience finally pay off

How do lions hunt?

Hunting is a team sport for the big cats

Lions will eat almost any animal protein, from ostrich eggs to elephants, depending on what is available. The lions on the Namib coast have even specialised to hunt seals. But their preferred prey is large grazing mammals, including wildebeest, buffalo and zebra. The animals live in open terrain and move in herds so it is very difficult to sneak up on them. Lions can sprint at 75kph (47mph) but this is still only slightly faster than a zebra (65kph) and the lion can sustain this speed for far shorter distances. All of this means that lions must plan carefully to achieve a kill.

The hunt begins from thick undergrowth or at night so the herd is unaware that they are being stalked. Several lionesses will make long flanking manoeuvres to encircle the herd and each one will spend up to an hour patiently inching forward to close the gap for that inevitable final dash. If they can get within 30 metres of the closest member of the herd, they have a good chance of success. When one lion begins a sprint, it is often a feint designed to drive the prey into the path of another lion, crouching hidden in the grass. With a single pounce they can cover five metres and will aim to knock the prey off its feet.

Once she connects, the lioness will grip relentlessly with her teeth to stop the prey from getting up again. Other lions move in for the killing blow. This is either by crushing the windpipe or clamping the lion's mouth around the entire muzzle of the prey.

ON THE MAP

Where lions attack

1. 1898, Tsavo River, Kenya. 35 killed
2. 1930-40, Njombe, Tanzania. 1,500 – 2,000 killed by a single pride over three generations
3. 1991, Mfuwe, Zambia. Six killed
4. 2004, Rufiji Delta, Tanzania. 35 killed

Man-eaters!

Of all the animals that attack humans, lions are the boldest and most aggressive

In 1898 a pair of nomadic male lions killed and ate around 35 railway construction workers, near the Tsavo River in Kenya, before finally being shot. Over a period of nine months, the lions evaded several attempts to trap them and were bold enough to crawl through thorn fences erected around the camp and drag workers from their tents.

Notorious as the Tsavo man-eaters are, deaths from lion attacks are much more common than they used to be because of human encroachment on lion conservation areas. Between 1990 and 2005, lions attacked at least 563 villagers in Tanzania alone. At least 70 people a year are killed by lions across the whole of Africa.

Lions are generally thought to prey on humans as a last resort. This may be because drought has reduced the numbers of their usual prey or it could be because old age or damaged teeth make them unable to hunt properly. But lions in perfect health will also eat humans if the opportunity presents itself. Mozambican refugees regularly try to enter South Africa by crossing the Kruger National Park at night and estimates of the numbers eaten by lions in the last few decades run into the thousands.

The rat-eating plant

Explorers discover a rare pitcher plant with a big appetite

In 2000, two Christian missionaries on the remote Palawan Islands of the Philippines become hopelessly lost while trying to install a radio tower on an uncharted jungle mountain. When they were rescued after 13 days without food, they told stories of a giant carnivorous plant, large enough to swallow a rat.

When explorers returned to the mountain seven years later, they discovered that the starved missionaries weren't hallucinating. The mountain was home to a brand-new species of carnivorous pitcher plant – also known as a pitfall trap or monkey cup – that the researchers named Nepenthes attenboroughii after the beloved British naturalist and TV host Sir David Attenborough.

Pitcher plants are evolutionary freaks. They're exclusively found in sodden, low-nutrient soils like bogs or fens. Desperate for sustenance, the plants have developed an 'unnatural' taste for flesh and blood.

The trap itself is formed from a modified leaf that balloons with water and air until its top snaps open, revealing a pool of lethal liquid surrounded by ultra-slick walls. The plant lures its prey with swollen red lips and a fragrant nectar that smells irresistibly corpse-like.

Anything that lands or stands on the curved lip of the trap – from tiny insects to fat rodents – will instantly slip inside, thanks to a waxy coating that flakes away on contact. When the creature hits the water, the plant excretes powerful digestive enzymes that immediately start eating through flesh and bone, even while the victim struggles to escape.

"Pitcher plants are evolutionary freaks"

Image © Stewart McPherson

5 TOP FACTS PITCHER PLANTS

1 Opportunity for opportunists
Some animals poach corpses from the pools of pitcher plants, even small, freshwater crabs.

2 Where to find pitfall traps
There are 91 species of Nepenthes in the world, over 30 found exclusively on the island of Borneo.

3 Poison ponds
Large pitcher plants can carry two or three pints of liquid.

4 Open for business
The lid of a pitcher plant does not snap closed like the Venus Flytrap.

5 Popular namesake
Other species have been named after Attenborough, including an anteater, a tree and a Jurassic marine reptile.

Learn more

For more information about pitcher plants visit **www.redfernnaturalhistory.com** where you can uncover more details and learn about the different species found across the globe.

5 TOP FACTS ANTS

Strength in numbers
1 Approximately 12,000 known species of ant compose around about 1.4 per cent of the world's total insect species.

Survival of the fittest
2 The family Formicidae are hardy little critters, who have existed on Earth for more than 140 million years, and aren't going anywhere soon!

Life expectancy
3 An ant Queen can live up to three years. Worker ants expect to live for a maximum of two, still impressive for an insect species.

Ant army
4 Eciton burchellii, a species of army ant, attack in formation with their swarm broadening to 15 yards, including up to 200,000 drones.

What's in a word?
5 In Japanese the word ant is intricately written by linking two separate characters, one meaning insect and the other loyalty.

DID YOU KNOW? *Ants communicate primarily with pheromones, chemicals secreted and smelled or tasted by nest mates*

The inner workings of an ants' nest

The fascinating social structures of the mighty yet minuscule ant species

Ants, or the family Formicidae, are an interesting species of insect, which show a distinct and complex social infrastructure. Known as an ant colony, this social cycle is dependent on hierarchy, with the Queen starting the proceedings.

Once an ants' nest is successfully built, the Queen, or reproductive female, will take up residence after nuptial flight and shed her wings. One or a few male ants then inseminate her. This can take place in the nest, while stationary in the air or on low vegetation or the ground when food foraging. She then resides in an excavated chamber. Here she will lay her eggs, emerging as larvae, feeding them from regurgitate liquefied musculature, related to the wings.

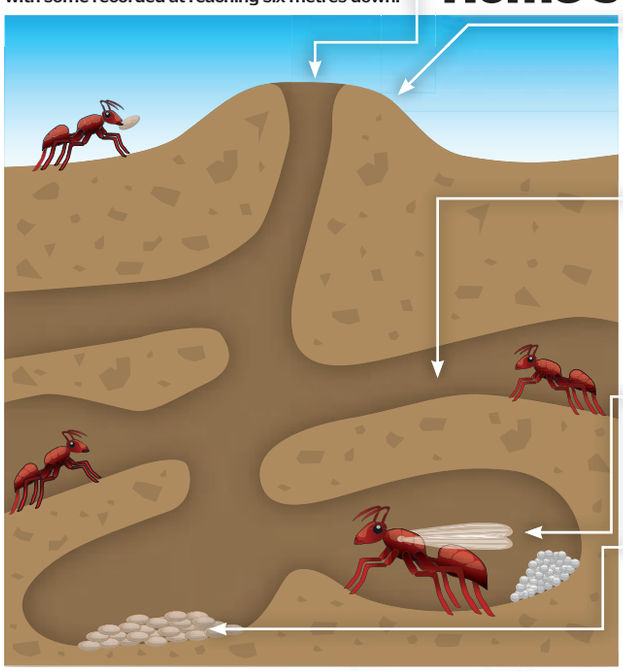
These initial numbers of worker ants are referred to as nanitics, spawning from eggs no bigger than 1mm in size. This life cycle – from larva, to pupa, to ant – often lasts from six to ten weeks. These are much smaller than subsequent workers, due to the ability of the Queen to only provide a limited amount of food, comparative to that which foraging workers later provide.

Initially the Queen is responsible for nest maintenance and defence, once larvae have reached maturity the Queen is only responsible for reproduction and populating the ant colony. It's now the ant workers turn to feed and sustain her majesty. This allows the colony to expand in population as well as territory and residence.

This of course takes a period of several years, after which the colony produces its first generation of sexuals, who will fly on the same day all at the same time, enhancing their chance to meet in the nuptial flight and to close the cycle. The reason behind this is also that the death of the Queen has devastating effects on a colony as ants seldom replace her, and have a survival expectancy of only several months after her demise.

Ants' nests house complete colonies, so they have to be pretty big. The majority of this species decide to build intricate layouts underground, with some recorded at reaching six metres down.

Home sweet home



Ant colonies are built and maintained by legions of worker ants. They carry tiny bits of dirt in their mandibles, depositing this near the exit of the colony. This forms what is know as an ant hill.

Each nest is an intricate labyrinth of tunnels and chambers that serve different functions and house different members of the ant colony. Each is interconnecting and has an opening, connected with the surface.

The Queen ant understandably has the freedom of her own chamber. It's here, in this excavated area, that she will repopulate the colony, laying all her eggs.

Other chambers are used as nurseries tending to larvae. There are also food larders, stocking sustenance for the colony, and resting quarters for those hard-working ants.

Ant social types

Every ant knows its place, and the job of each one is just as vital as the next. But just what are the roles of the different ant classes?

NAME OF ANT:
Ant Queen
ROLE:
The Queen establishes but does not rule. Her role is to reproduce, and ensure the longevity of the colony.

NAME OF ANT:
Worker
ROLE:
Perhaps the smallest, these ants care for the Queen and her young, build and repair the nest and forage for food.

NAME OF ANT:
Soldier
ROLE:
Significantly larger worker ants that are named as such due to their larger heads, and stronger mandibles.

NAME OF ANT:
Drones
ROLE:
Male ants, or drones, live only a few weeks or months, and are solely responsible for inseminating young queens.

"Eventually stalagmites and stalactites meet to form columns"

Why light attracts moths

Understanding their obsession with light

You're likely to have seen it, a moth fluttering near an outside light at night, spinning around aimlessly. The insect's intriguing behaviour is down to phototaxis, an animal's automatic reaction to or away from light. A moth is a positively phototactic bug, which means it's fascinated and charmed by bright lights, for example a car's headlight, a porch light, or a candle flame. The latter unfortunately doesn't have a happy ending. It is also believed that a moth uses a light at night as a form of navigation. It is mainly the moon that guides a moth, but lamps and other such bright, glowing objects can confuse the creature as it passes by. This sends it in a bit of a dazed and circular pattern around the light, until the Sun comes up when it uses the day to regain its strength.

It's believed that moths use light for navigation

DID YOU KNOW?

World's largest moth...
Found mainly in southeast Asia, the Atlas moth (or attacus atlas) can have a total wing surface area of 65 square inches and their wingspan can reach up to 12 inches (30cm).

Stalagmites and stalactites explained

Acid induced spikes – sounds torturous, but it's only nature

Where there's a stalagmite there's a stalactite, and they are never far apart. These two spiked columns are found in underground limestone caves all around the world.

They're the results of one extremely long drip along with the process of evaporation. Seeping acidic water works its way through the rock above until it hits the roof of the cave. This dripping solution dissolves the limestone-caked cave and is carried in a downward column called a stalactite. The water drops gradually edge their way through the middle of the stalactite and drip onto the floor. If the water falls and doesn't evaporate before touching the ground it then forms the rising cones beneath, known to us as a stalagmite.

These two spikes can sometimes touch each other head on, and eventually they'll join up to create what's technically called a 'column'.

All it takes is a drip to get the process going

5 TOP FACTS GLACIERS

10% of the Earth's surface

1 The huge number and vast size of the likes of Antarctica means that glaciers spread over an enormous ten per cent of the Earth's land area.

Alaska, home of the glacier...

2 The US state of Alaska has as many as 100,000 unnamed glaciers, although thinking up 100,000 different names wouldn't be an easy task...

70 metres more sea

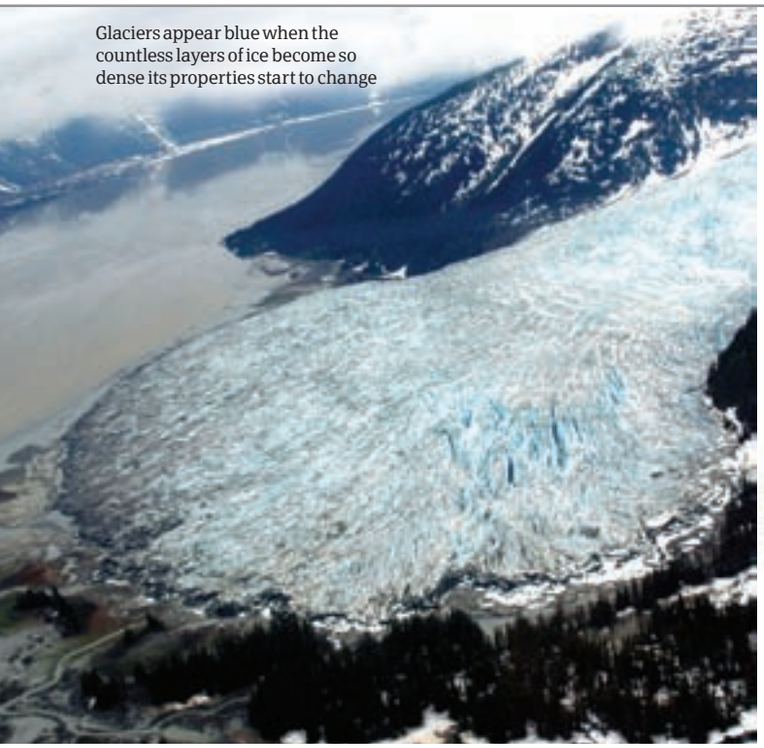
3 In a very doomsday-esque scenario, if all global land ice melted, sea levels would rise by approximately 70 metres (230ft).

Formidable freshwater force

4 Glaciers hold within them up to 75 per cent of the world's entire freshwater supply, 61 per cent of that lies within the Antarctic ice sheet.

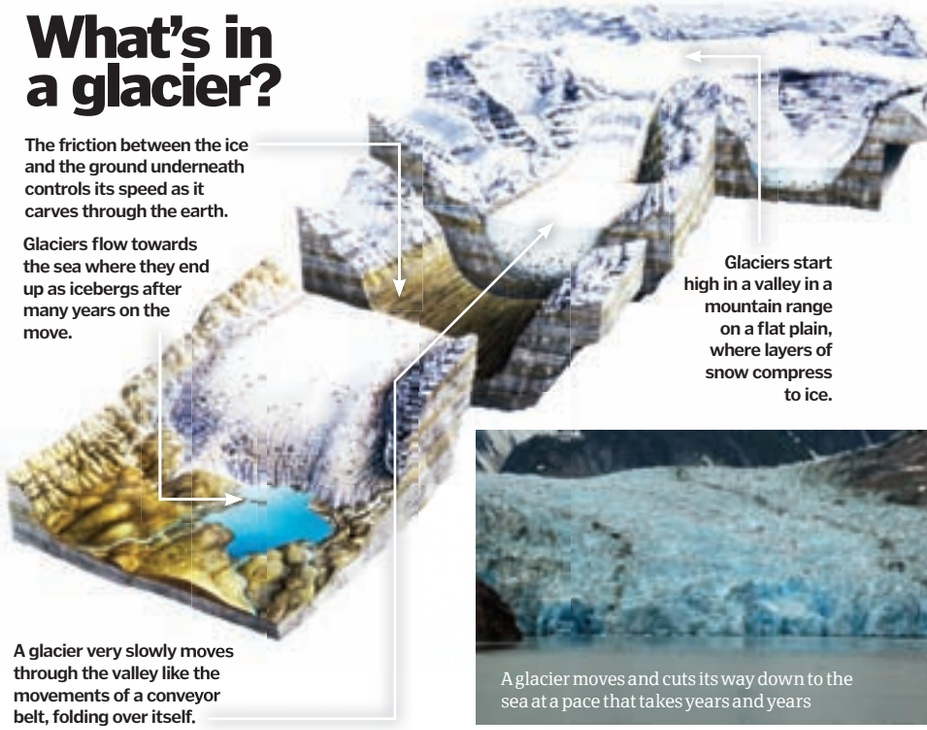
Fastest glacier on Earth

5 Pakistan's Kutiah Glacier holds the record for the fastest glacial surge in 1953, at an average of 112 metres each day.



Glaciers appear blue when the countless layers of ice become so dense its properties start to change

What's in a glacier?



The friction between the ice and the ground underneath controls its speed as it carves through the earth.

Glaciers flow towards the sea where they end up as icebergs after many years on the move.

Glaciers start high in a valley in a mountain range on a flat plain, where layers of snow compress to ice.

A glacier very slowly moves through the valley like the movements of a conveyor belt, folding over itself.

A glacier moves and cuts its way down to the sea at a pace that takes years and years

How glaciers are formed

Hostile, baron and on the move – will glaciers decide our future?

Snow, intriguing as it looks and as wonderful as it is to play with, has a power that is so great it can cut its own valleys and even reshape entire mountains. Glaciers are fundamentally fuelled by snow, but the conditions have to be just right for them to actually form. The climate has to be cold enough so that newly fallen snow doesn't melt when the summer months arrive. Year after year fresh snow needs to be able to build up for a glacier to form and finally begin to move. Too steep a slope and the unborn glacier will simply avalanche.

A glacier begins high in mountain valleys in places such as Alaska, New Zealand, and in the polar regions – the Arctic and Antarctic. Tropical glaciers also form across continents such as Africa, and in mountain ranges including the Himalayas. Unfortunately these types of glaciers have been thinning in the latter half of the 20th Century as the result of global warming. Their future prospects are looking somewhat bleak.

Glaciers form by snowfall after snowfall, and countless layers compressing on top of each other. This overwhelming weight of the snow forms a huge swell of ice in a gap between two mountains. The unstable, mountainous river begins to move and flow in a frozen state. Helped by gravity and combined with its own tremendous weight, in a head over heels fashion it slides down the valley and grinds its path in the landscape that confronts it. The ice at the base of a glacier begins to melt, which is down to heat from the earth and the extreme pressure from the ice at the top.

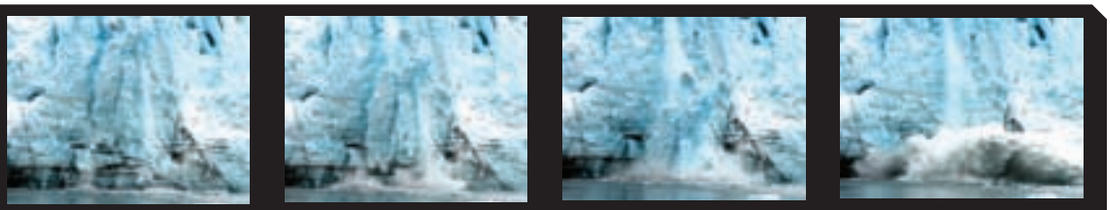
A glacier moves in two ways, either retreating or advancing, though this direction depends on which way its cone-like nose happens to be facing. This is, however, slower than a snail's pace as it moves towards the sea, or spreads across a plain. But the chopping and remoulding of the landscape is even more severe when a glacial surge occurs. It picks up pace and wipes over its surroundings at a rate of several metres each day for weeks and sometimes even months on end.

It's not a rare sight to see a glacier take on a blue hue to its ominous appearance. This cool colouring is a sign of its density, with mounting pressure over years of layers compressing into other layers. From beautifully white and fluffy flakes, a glacier takes on an incredible blue ice, as the air between the layers is forced out, and the properties of ice begin to change.

Glaciers are one of the world's most useful indicators of how our global climate is changing. As global warming takes a firmer grip, most glaciers today are retreating in their movements. In countries such as India the melted glacial ice provides much of their fresh water, but this losing battle could result in desperate measures. This is why a glacier is recognised as one of the most crucial clues to what is happening and what is likely to happen to the future of our world.

Glacial calving

Ice breaks off when a glacier meets the sea



Calving causes large masses of ice to break away from the main body of the glacier. This is how many of the world's icebergs are formed

MINI-GUIDE KEY
Eco-home plan layout

1 Photovoltaic panels
2 Wind turbines
3 Rainwater harvesting
4 Geothermal energy
5 Recycling bins
6 Clothes drying
7 Biomass store
8 Vegetable patch
9 Hard surface run-off

An eco-home needn't sacrifice comfort and design

About the eco-house

FKDA is an architectural practice based in Manchester in the UK. Its take on the eco-home isn't a one-size-fits-all solution, but rather a modular approach. This means that basic designs can be combined according to the requirements of the buyer. This two-storey family home is the standard model; there's also a three-storey version for larger families and a single-storey version for the elderly. FKDA says that its homes are capable of achieving total carbon neutrality (using or exploiting none of the stuff), but it provides variable levels of carbon usage so families don't have to change their entire lifestyle.

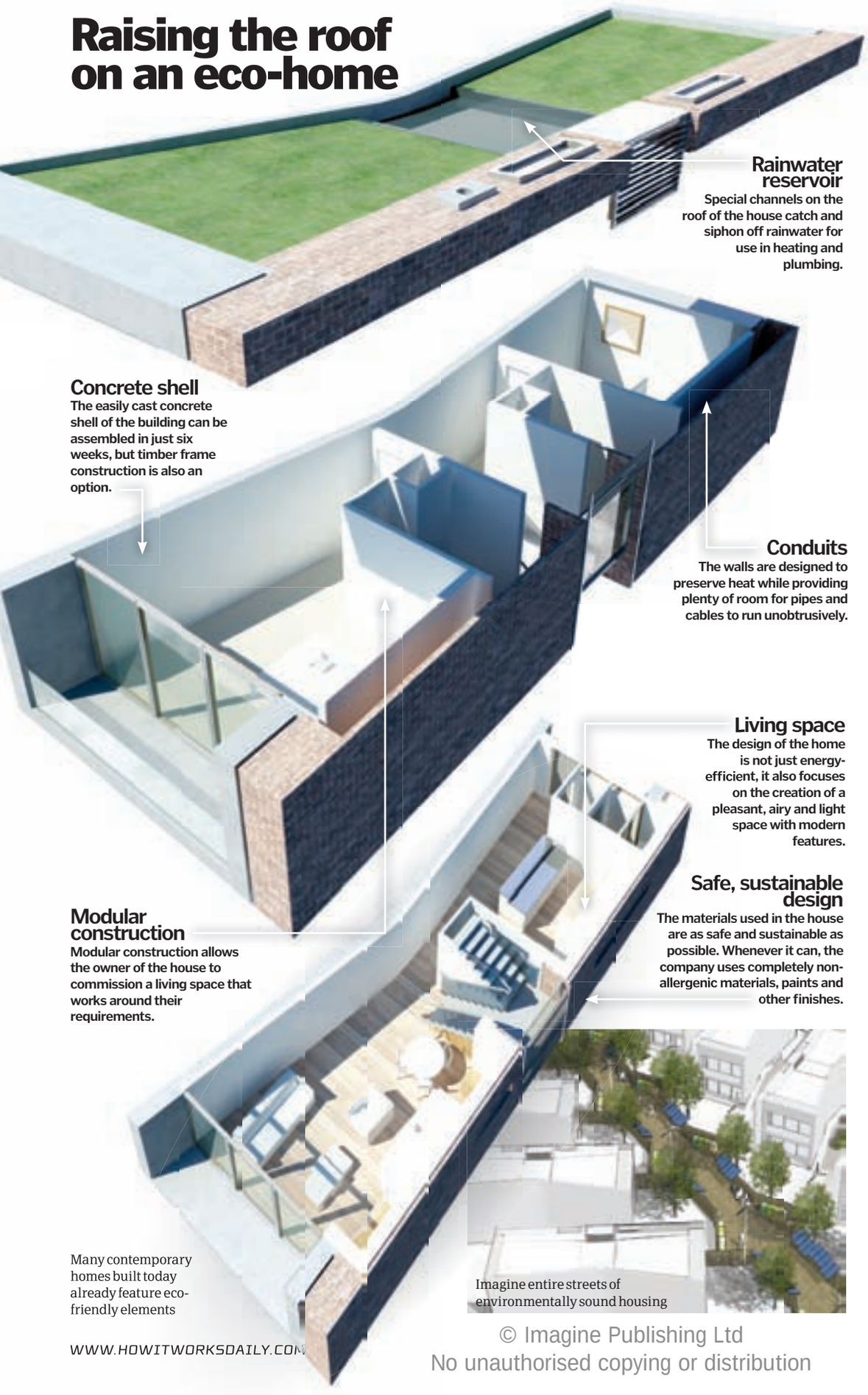
How does an eco-home work?

Why the home of the future will help us to save money and resources

The idea of an eco-home can conjure visions of Roger Dean-style cave dwellings and treehouses designed to be small, round and warm. These days, however, there is great interest in energy efficiency among consumers who don't want to live like Hobbits. Energy-efficient homes now look sleek and contemporary and provide a range of ways to live a more sustainable lifestyle.

Eco-friendly ways of using energy are now more affordable, with gadgets like wind turbines and solar panels providing great sources of electricity and heating respectively. Geothermal heating is a newer development, making use of the heat deep in the Earth's crust to warm our homes. Lighting, heating and power are the biggest factors in energy use, and it's surprising how much of these resources the average home wastes. Water is another resource that needs sustainable management, so homes are now being developed with rainwater channels and reservoirs to save rain for non-drinking use in your plumbing and heating, while run-off areas can stop water being lost by channelling it back to either your reservoir or the water table itself. Gardens with fruit trees or a vegetable patch are being rediscovered as a nutritious way of saving money sustainably too.

Raising the roof on an eco-home



Rainwater reservoir
Special channels on the roof of the house catch and siphon off rainwater for use in heating and plumbing.

Concrete shell
The easily cast concrete shell of the building can be assembled in just six weeks, but timber frame construction is also an option.

Conduits
The walls are designed to preserve heat while providing plenty of room for pipes and cables to run unobtrusively.

Living space
The design of the home is not just energy-efficient, it also focuses on the creation of a pleasant, airy and light space with modern features.

Safe, sustainable design
The materials used in the house are as safe and sustainable as possible. Whenever it can, the company uses completely non-allergenic materials, paints and other finishes.

Modular construction
Modular construction allows the owner of the house to commission a living space that works around their requirements.

Many contemporary homes built today already feature eco-friendly elements

Imagine entire streets of environmentally sound housing

Tips for a green life

You don't have to move to an eco-home to do your bit

Changing a few habits can make a dramatic difference, you don't have to transform into a lentil-eating hippy to help save the planet. Turning your heating down by a few degrees is more energy efficient than blasting out the heat, and having insulation in your attic and wall cavities means that your home will still be warm and cosy. Take showers instead of baths, or recycle your bathwater to water plants or do household cleaning. Waste food, especially vegetables and fruit, can be used as compost, which you can use to grow your own food. Turning off household appliances when they're not in use is another simple but highly effective way to conserve energy. Think about whether you really need your computer and the TV on concurrently and use one device at a time.

Plan for the future

Simple gadgets for an energy-efficient home

Photovoltaic panels
Use solar power to light and heat your home with the Sun's energy

Wind turbine
Generate electrical power by making use of the wind's energy

Rainwater harvesting
Use rainwater to flush toilets and in central heating

Geothermal energy
Make the most of the heat from the Earth's crust to heat your home

Clothesline
Dry your clothes the old-fashioned way instead of tumble drying

Grow your own seasonal fruit and veg
Not only will it save on supermarket packaging, but it also tastes better

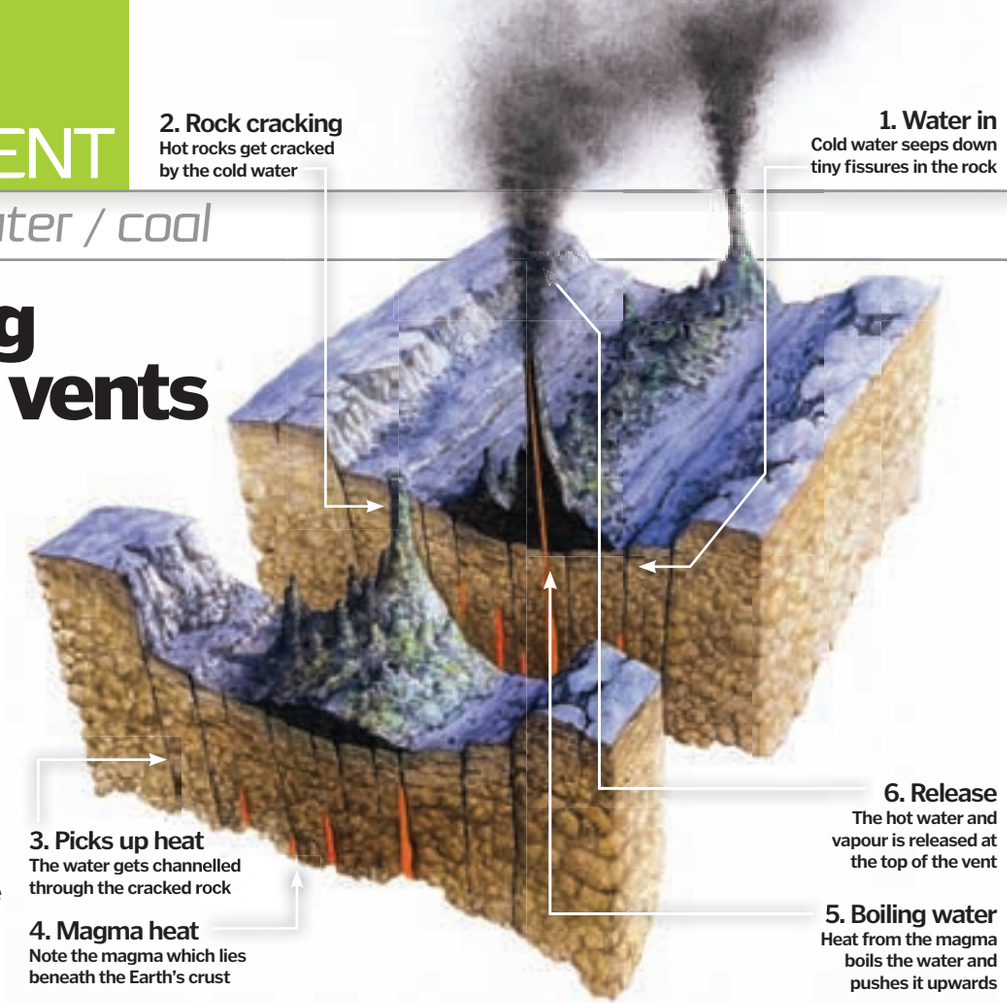
Biomass store
Produce compost to fertilise your garden and your vegetable patch

Run-off
Make sure that excess water runs off back into the water table

Understanding hydrothermal vents

How geysers and underwater volcanoes can get you in hot water

Hydrothermal literally means hot water. In some areas of the Earth's crust, notably Yellowstone Park in the US and in the oceans off New Zealand, heated water is pumped out of the ground or the seabed. There isn't a giant jacuzzi under there, in the case of underwater vents it's sea or lake water that has been pulled into a hole, in ones on land it's either groundwater or rainfall deposits in the same situation. But it's not any kind of hole – it's a vent directly through the Earth's crust, and that means magma. That's not to say that the fissures from which vents issue are necessarily deep – often they're at the edges of tectonic plates or in volcanic regions where the crust is thinner and less stable. The heat from the magma beneath the vent causes the water that's been pulled in to heat up. As it reaches boiling point it's expelled outwards, creating bubbling hot springs.



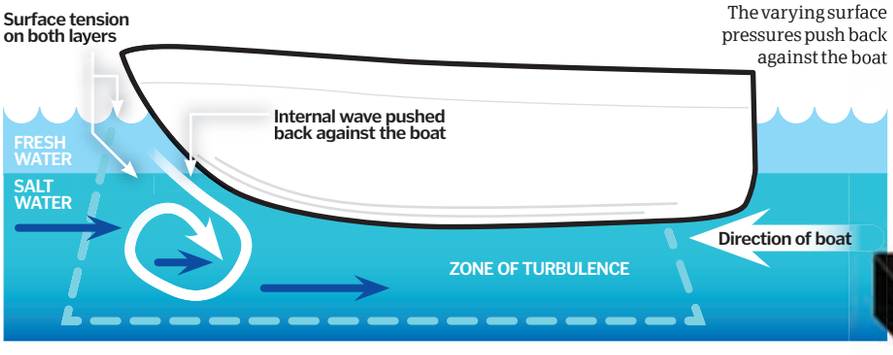
What is dead water?

The scientific explanation for a sailing superstition

Ever seen the bubble baths made up of two different coloured liquids, one floating on top of the other? That's essentially how dead water works. But far from providing a relaxing soak, this eerie aquatic phenomenon becalms boats and can bring ships to a dead stop. It creates a dense surface that produces an effect that's literally like trying to sail through toffee.

Dead water is created when a layer of fresh (or not so fresh) water floats on top of a layer of seawater and the two don't mix. Both layers effectively have their own surface tension, and because they're separate and not mixed, the effect is cumulative – it adds up, so anything caught between the two layers has to move against the weight and tensile strength of both of them. This creates so-called 'internal' (underwater) waves which create even more resistance for anything trying to move through them. So what makes this happen? Some areas in which it can occur naturally are areas of relatively slow water movement where fresh and salt water meet but don't necessarily mingle, like river deltas, glacial fjords and mangrove swamps. This provides the two water types necessary, but another key factor in the creation of dead water is the waves that are created in the area. Long waves rolling through shallow water don't mix the two types of water as much because the individual particles of water tend to move on horizontal paths rather than up and down, so dead water is more likely in shallow, calm areas near flat shores, undersea plateaus or ice floes.

Lack of wind is another factor – a stiff breeze will soon mix the surface water with the denser salt underneath. Sadly, pollution – particularly from sewage – is also a factor in the creation of dead water zones.



Creating coal

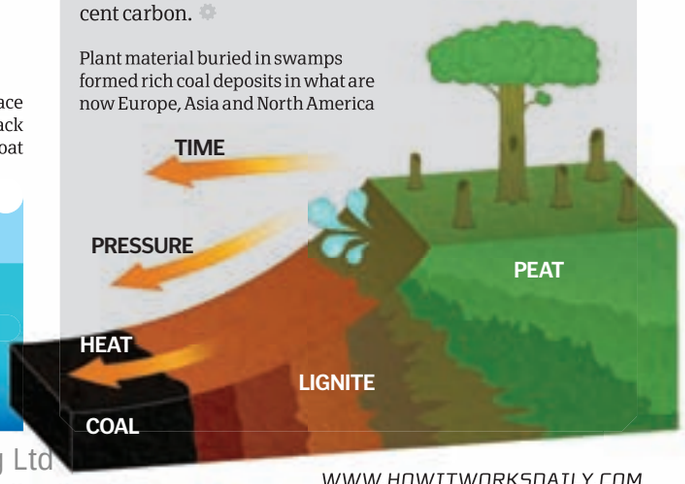
Millions of years of solar energy trapped in a dirty black rock

Over 300 million years ago, long before the first dinosaurs, the Earth was covered in vast swamps. Colossal trees and towering green plants flourished. As they died, their carbon-based remains sank to the swamp floor, piling up as a thick layer of peat.

As the millennia passed, these ancient peat bogs were compacted by progressive layers of sediment. In some cases, the peat was compressed further by the formation of ancient seas or lakes. All of this pressure generated immense heat that altered the chemical make-up of the peat, making it more and more carbon-rich.

When carbon content reaches 40 per cent, peat becomes lignite coal, a low-energy brownish sedimentary rock. With more time and heat, coal gets harder and purer and generates more energy when burned. The hardest and most energy-rich coal is anthracite, composed of 90 per cent carbon.

Plant material buried in swamps formed rich coal deposits in what are now Europe, Asia and North America



5 TOP FACTS NORTHERN LIGHTS

The neighbours have them too
1 Other planets including Jupiter, Saturn, Uranus, Neptune and many of their moons have their very own aurorae.

Solar music makers
2 The massive electrical activity of the northern lights transmits eerie crackling and whistling noises over radio receivers.

Biggest display ever
3 A massive magnetic disturbance back in 1989 caused visible aurarae as far as Texas and even Northern Australia.

The 'stuff' of space
4 Amazingly, a phenomenal 99 per cent of visible matter in the universe is actually made up of plasma of one sort or another.

Pole dancing
5 The North and South Poles have switched places 400 times in the past 330 million years, the last occurrence being 780,000 years ago.

DID YOU KNOW? *The colours in the aurora borealis consist of red, blue, violet and green*

Northern lights

Stormy space weather produces the world's biggest neon sign

Space weather

The cold vacuum of space seems an unlikely place for a storm. But that's exactly what happens when a solar flare explodes into the Sun's upper atmosphere, instantly heating nearby gasses to millions of degrees.

The extreme heat causes gas atoms to split into positively charged ions and negatively charged free electrons. This supercharged soup of ionised gas is called plasma. The Sun emits a constant stream of plasma in all directions at a speed of 500km/s (a million mph). But when the flow of plasma becomes a flood, the Earth is in for some bad space weather.

Geomagnetic storms cause more than the majestic northern lights. They can warp the Earth's magnetic field so badly that satellites are knocked out of orbit and invading electrons overwhelm power grids. In 1989, 6 million people in Montreal, Quebec lost power for nine hours thanks to a particularly strong solar storm.

"Gentle solar winds turn into geomagnetic storms"

The aurora borealis, or northern lights, taken by astronaut Donald R Pettit, on board the International Space Station (ISS)

All Images © NASA

What would the North Pole tourist bureau do without the northern lights? Ten-month winters don't make for good travel brochures. But only here, in this most inhospitable open-air theatre, can you witness the most hauntingly beautiful light show ever conceived. Curtains of shimmering, chameleon-hued light as unpredictable as an artist's temper.

The scientific explanation behind the aurora borealis ('northern dawn' in Latin) is almost as improbable and magical as the lights themselves. The Earth, it turns out, is constantly bombarded by highly charged particles blown around by solar winds. Few of these particles ever reach the atmosphere because they are deflected by the Earth's magnetic field.

But every so often, the gentle solar winds turn into geomagnetic storms. Solar flares and coronal mass ejections (CME) – explosions of solar material into interplanetary space – can send powerful waves of charged particles toward the Earth. As these cosmic electrons collide with the Earth's magnetic field, they generate millions of amps of electric current that arc along the magnetic field toward the poles.

If the force of a geomagnetic storm is severe enough, particles will breach the magnetic field at the poles, creating what is essentially the world's biggest neon sign. As the supercharged electrons pass through the atmosphere, they excite gas atoms like oxygen and nitrogen.

The excited gasses emit different coloured lights depending on their altitude and the power of the surge. Low-altitude oxygen is responsible for the fluorescent green hues and high-altitude oxygen produces those brilliant crimson reds. Nitrogen flares up as shades of blue and purple.

The celestial light show is visible at the South Pole as well (there, it's called the aurora australis), but the Antarctica tourist board is woefully understaffed.

This month in **Technology**

Meet the next generation of robots that are fighting wars and saving lives in our main technology feature on page 36. It's not all androids, we also take a look at hydroelectric power and find out about constructions like the Hoover Dam that can turn water power into electric power.

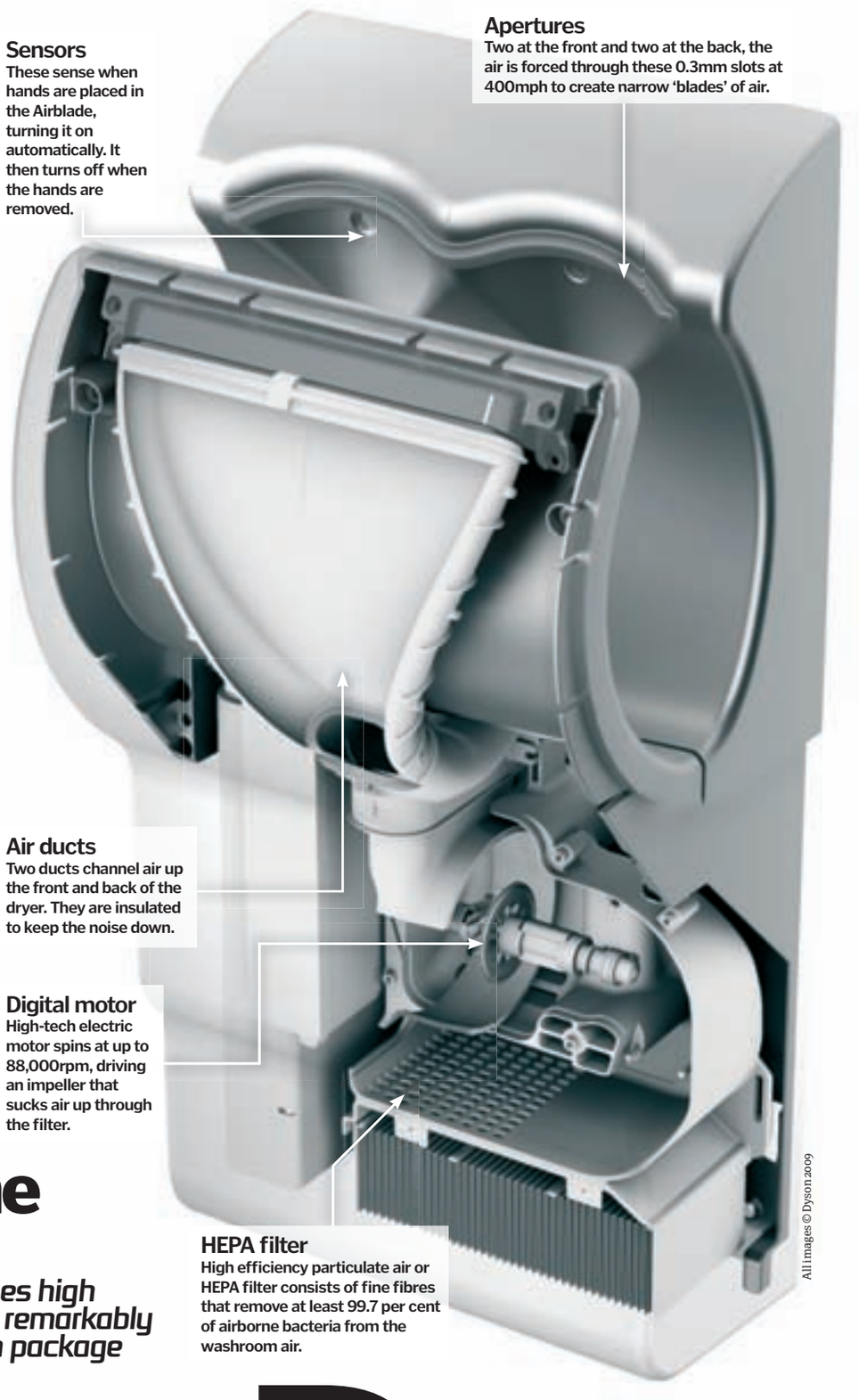
TECHNOLOGY

Conventional warm-air hand dryers never seem to do a great job of actually drying your hands. That's because they simply blow out a low-power stream of warm air that slowly evaporates the water from your hands.

Indeed, inventor Sir James Dyson was so fed up with having to wipe his hands down his trousers after using a dryer, that he took a fresh look at the problem and came up with the Dyson Airblade – a dryer that works much faster, more efficiently and without spreading germs.

To use the Airblade, simply place your hands in it and draw them slowly up. 'Blades' of cool air travelling at 400mph and driven by a special digital motor scrape the water from your hands, leaving them dry. And the Airblade takes just ten seconds to dry your hands, whereas a conventional dryer will take up to 44 seconds.

What's more, because the air has been effectively filtered as it entered the Airblade, it's free of bacteria, which makes it more hygienic. In fact, the Airblade is said to be the world's only dryer that has been certified as hygienic by NSF International, the public health specialist. Other dryers simply suck in germ-filled air from the washroom, warm it up and blow it back out, germs and all.



All images © Dyson 2009

Inside the Airblade

The Airblade combines high technology within a remarkably compact and stylish package

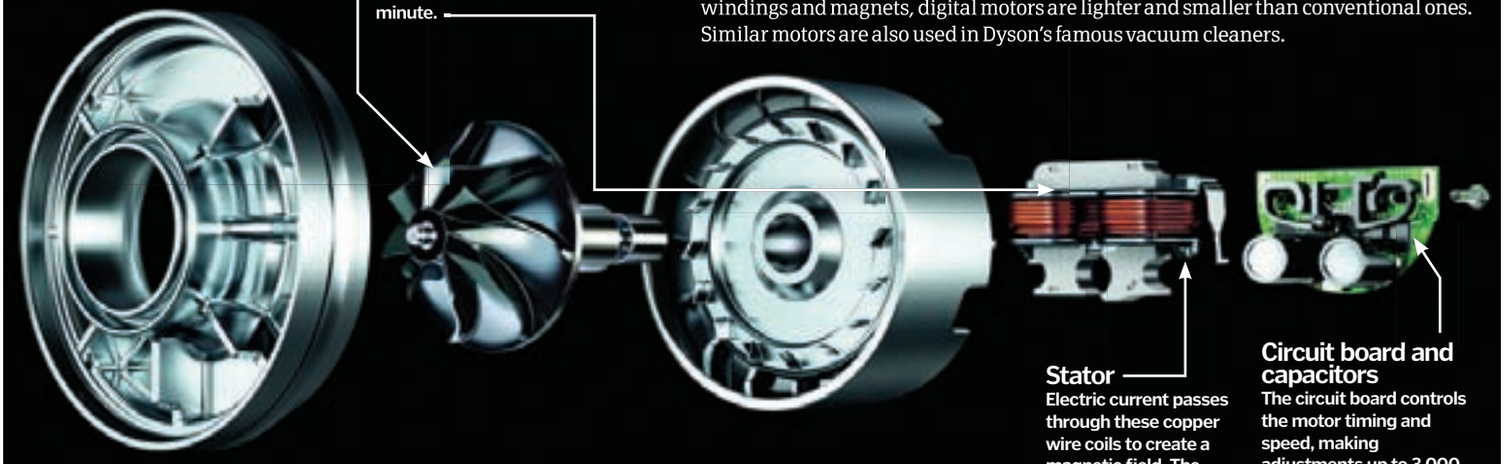
The Dyson

DID YOU KNOW? *The Airblade is accredited by the British Skin Foundation and the Royal Institute of Public Health*

The Dyson digital motor

The secret of the Airblade lies in a special electric motor developed by Dyson's engineers. Conventional electric motors use brushes which create friction, wear out and produce carbon dust. They also have heavy, bulky magnets and windings.

The Dyson digital motor, on the other hand, dispenses with brushes and instead uses digital pulse technology to spin at high speed. Because they don't have such large windings and magnets, digital motors are lighter and smaller than conventional ones. Similar motors are also used in Dyson's famous vacuum cleaners.



Impeller and vane diffuser
The three-dimensional impeller is designed to suck air in and through the vane diffuser in an efficient manner.

Neodymium magnet
Neodymium is a very strong magnetic material. The rapidly alternating electromagnetic field of the stator causes the magnet to spin at up to 88,000 revolutions per minute.

Stator
Electric current passes through these copper wire coils to create a magnetic field. The polarity of this field switches rapidly from north to south.

Circuit board and capacitors
The circuit board controls the motor timing and speed, making adjustments up to 3,000 times a second. The capacitors supply current to the circuit board.

How it dries your hands

The blasts of air dry your hands as you place them into the dryer

Not only does the Airblade dry your hands, it's the only dryer that's been certified hygienic by NSF International

Impeller factor

The impeller's aerodynamic design means that its continuously curving blades spin at phenomenal speeds. The airflow produced is then channelled up and through the vane diffuser, as well as cooling other components of the system.

5 TOP FACTS THE AIRBLADE

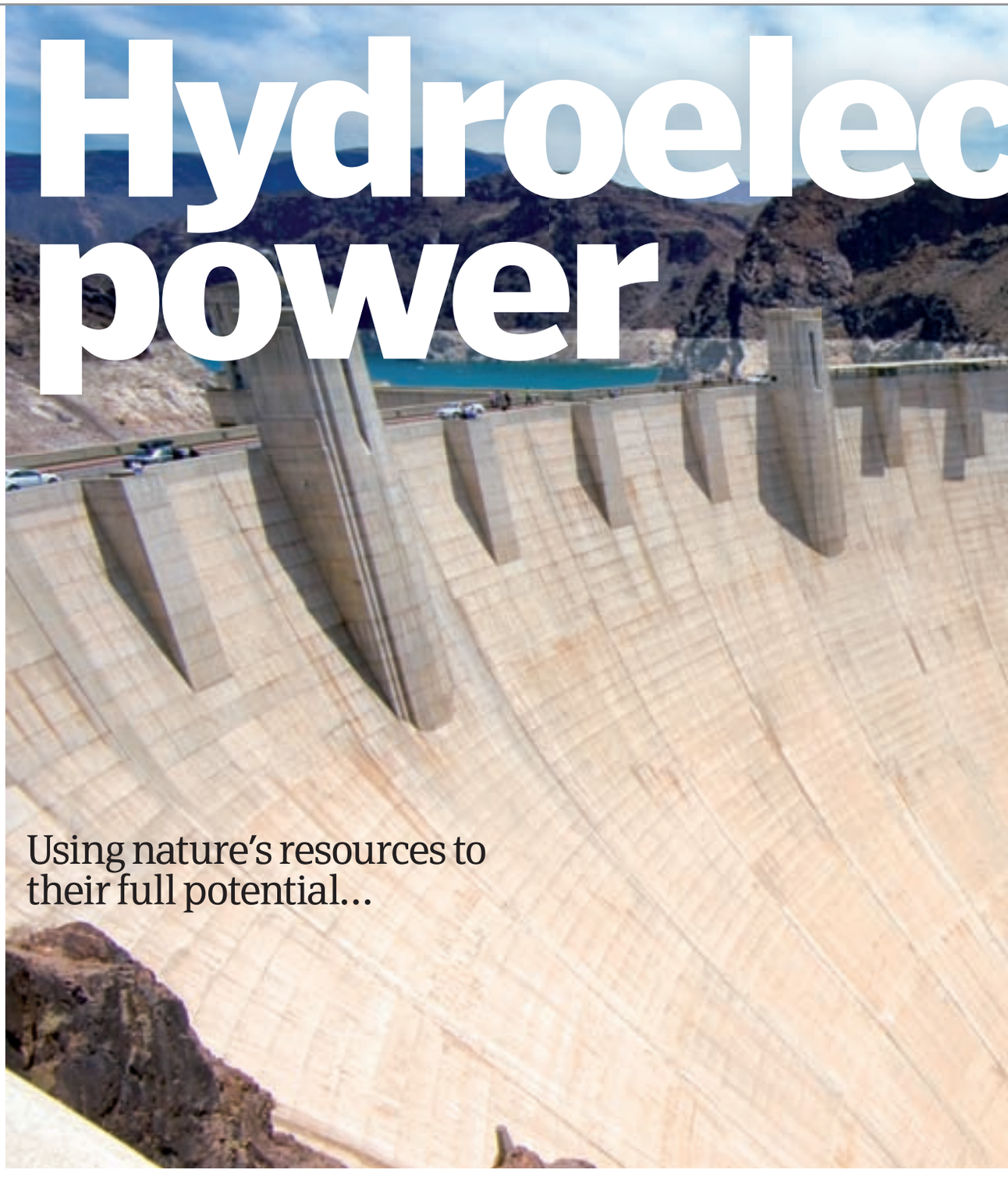
1. **High tolerance** There is just 0.3mm clearance between the impeller and its housing.
2. **Super strong magnet** The neodymium magnet is ten times stronger than a typical everyday magnet.
3. **Super sucker** The Airblade sucks in 37 litres of air every second.
4. **Efficiency dryer** The Airblade uses up to 80 per cent less energy than a conventional dryer.
5. **Cheaper than paper** For the price of one paper towel, the Airblade dries up to 19 pairs of hands.

At last, a hand dryer that doesn't leave you wiping your hands down your trousers!

n Airblade

Transforming water power to electric power explained

Hydroelec power



Using nature's resources to their full potential...

Head to Head DAMS

1. The Three Gorges Dam

Location: Yangtze River, China
Size: It's 2,335 metres long, 101 metres wide and 115 metres at its thickest point. It took 15 years, approximately £25 billion and nearly 14 million tons of cement and materials to construct it.
Facts: 34 turbines weighing in at a 6,000 tons each generate 22,500 megawatts for an annual output of 60.7 terawatt hours per year in 2009. It is the world's largest electricity-generating plant of any kind.

2. Nurek Dam

Location: Vakhsh River, Tajikistan
Size: The Nurek is an earth fill dam finished in 1980 when the Soviet Union had control of Tajikistan. At 300 metres it is the world's tallest dam, though the Rogun Dam has a taller proposed height for when it's eventually completed.
Facts: A comparatively modest nine hydroelectric turbines have a total power output of three gigawatts, but amazingly, since 1994 this has been enough to supply 98 per cent of the nation's total electricity needs.

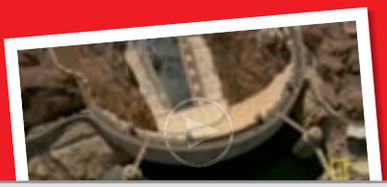
3. Verzasca Dam

Location: Lago di Vogorno, Switzerland
Size: Not the largest nor the tallest dam at 220 metres high
Facts: The site of the scene where Bond dove off into the Verzasca river below in *GoldenEye*, it's one of the most famous dams worldwide.

Water has been used to power man-made mechanisms for hundreds of years, mostly in food production in the form of a mill wheel to grind corn. But using the kinetic energy of water probably became a reality earlier than you thought. In 1878, inventor Lord Armstrong lit his home in Northumberland using only the power of a nearby waterfall. It's not until the latter half of the 20th Century that we began to take advantage of the massive potential of hydroelectric power.

Intriguingly, both the dirty and environmentally unfriendly coal power plants and clean, green hydro-power use almost exactly the same technology to generate power. Central to a coal-fired plant is a turbine: coal is burned to produce heat energy, which is used to boil water into steam that then drives a turbine. Hydroelectric power removes the coal and steam elements and instead, flowing water turns the blades of each installed turbine.

By damming a river next to a drop in elevation and releasing a controlled flow (and creating a large body of water behind the dam called a reservoir), you can effectively harness the Earth's gravity as an energy source. It's based on the principles discovered by physicist Michael Faraday: when a magnet moves past a conductor, it creates electricity. When the water flowing



DID YOU KNOW? *Between 13,000 to 16,000 people cross the Hoover Dam every day*

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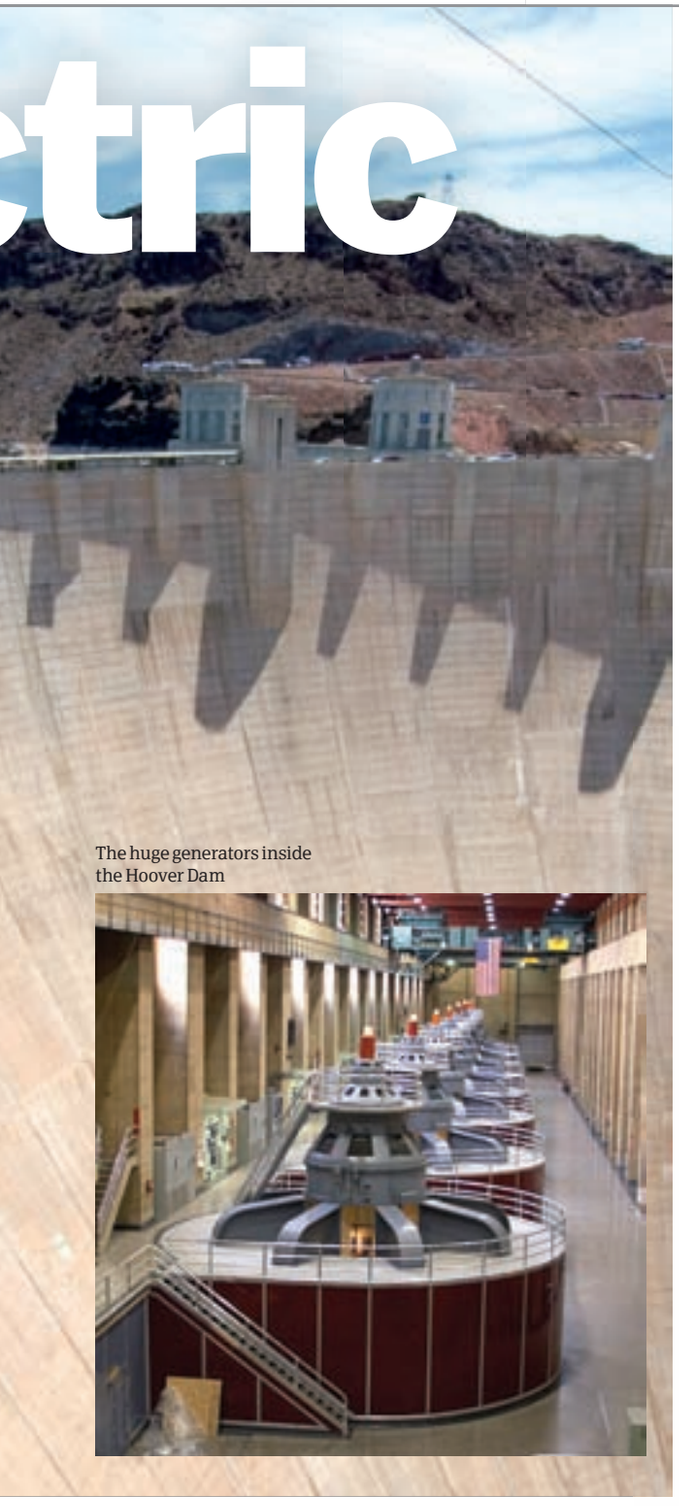


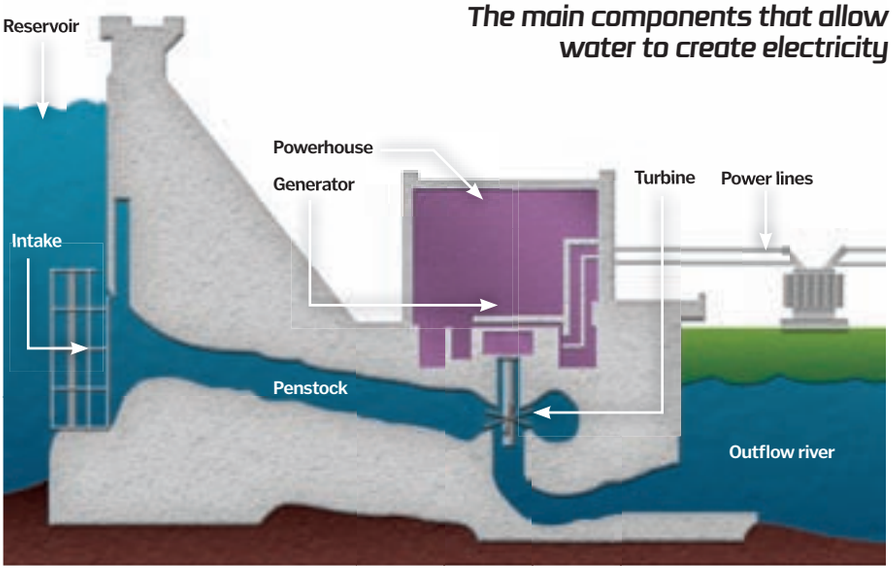
The huge generators inside the Hoover Dam

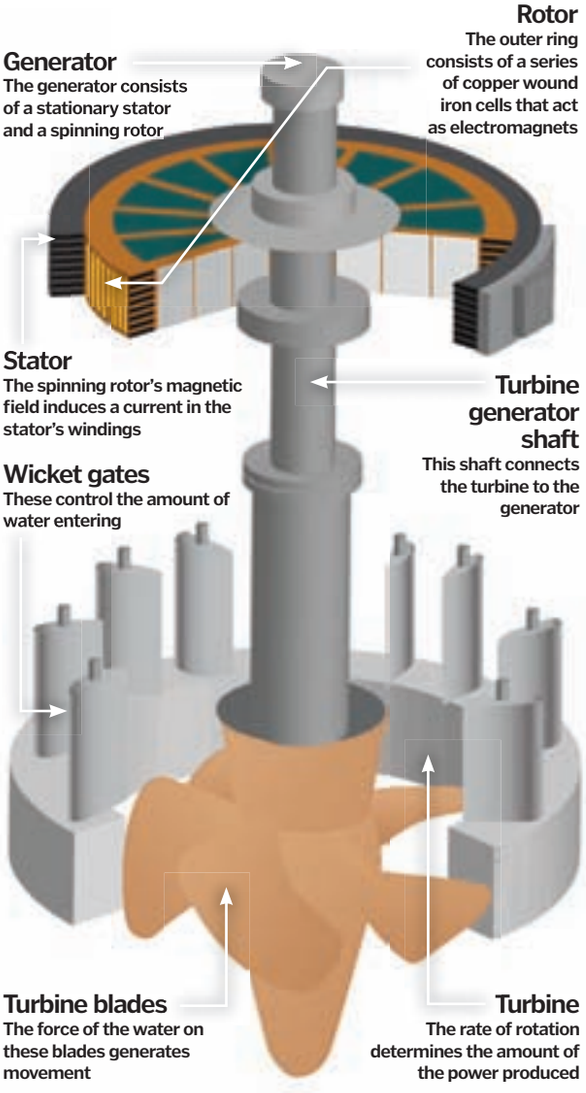
through a hydroelectric turbine turns the blades it rotates a shaft attached to a large disk called a rotor at the opposite end. The rotor is made up of loops of wire with current circulating through them, wound around stacks of magnetic steel. When active, the turbine propeller turns the rotor past the conductors located in the static part of the turbine, known as the stator.

Modern technology in even a single large turbine (which can weigh thousands of tons) can generate an enormous amount of power, but the cost-effectiveness of building the dam as well as the environmental and economic impact of flooding the area behind it can prohibit such ventures.

Inside the dam

The main components that allow water to create electricity





TYPES OF... DAM

1. **Saddle** Often constructed as an auxiliary to the main dam, at a dip (or saddle) where water would otherwise escape.
2. **Diversionary** Often a controversial construction, these are created with the pure intention of diverting a river from its course.
3. **Dry** These are designed to control flooding, allowing the river to flow freely except in times of intense rainfall where flooding is likely.
4. **Overflow** These are made with the intention of the river flowing over the top of the dam, usually to measure flow and for drinking water.
5. **Check** Check dams are used to slow the rate of flow of the river with the expressed intention of controlling soil erosion.

Learn more

For more information about the Hoover Dam visit **http://www.pbs.org/wgbh/americanexperience/hoover/** where you can watch a video on how the dam was built and the mammoth task that was involved.

"A connected GPS has a permanent net connection for downloading data"

Map view
Locations and nearby points of interest are displayed on the map

Text-to-speech
Text-to-speech will read website information to you while you drive

Instant updates
Live Traffic gives you instant updates on the state of the roads

Meet Garmin nüvi 1690, the new breed of satnav that gives you live updates via cellular connection

Connected GPS

Satnav devices have got the A-to-B route planning down to a fine art – simply load up your destination and the combination of 3D mapping and voice guidance will get you to where you want to go. So where does satnav go next? The answer is connectivity. The new Garmin nüvi 1690 comes with a built-in SIM card that creates a permanent data connection to the internet, enabling the device's nuLink software to download relevant information about your journey as you drive, from traffic to weather, to real-time fuel prices at nearby petrol stations.

It's easy too, and perfectly integrated into the all-round functioning of the device, and turns the satnav system into a kind of 'location aware' internet tablet. In practical terms this means you can use the Google Local Search feature to search for, say, Indian restaurants, and the resulting list of results will show said establishments listed in order of their proximity to you. And because it uses exactly the same technology that powers Google on a desktop computer you get all the added interactive benefits of that service as well – things like restaurants and hotels will also often be accompanied by user ratings and reviews, so you're not simply finding your nearest restaurant, you're finding the best one. This Google search feature is one of the highlights of nuLink, complementing the traditional points of interest database in the device with more relevant and up-to-date information.

The other key benefit of the service is the live traffic information that it provides. This gives you the chance to see any potential jams on your route ahead, and you can set the system to automatically reroute you to avoid them, or you can take your chances and deal with any possible delays on a case by case basis. Regular build-ups of traffic, for example, might have cleared by the time you reach them, while serious road works will most likely not have.

By having its always-on data connection, the Garmin nüvi 1690 is able to deliver other information straight to you as you drive. The fuel price service removes the 'cat and mouse' approach to filling up on a long journey, nuLink shows you the prices at all your upcoming petrol stations so you can easily compare. Another useful money-saving feature is Garmin's ecoRoute application. Enter a few details about your specific make of car and the way you drive and ecoRoute will plot your journey in the most fuel efficient way – it's unique to you, will show exactly how much money you will save, and as an added bonus helps you cut down on your carbon footprint as well!

These features show the direction that tomorrow's satnav systems are heading. No more are they mere digital atlases, but fully interactive and personalised devices that deliver highly contextualised information. Whether you want to know what the weather is like at your destination, whether your flight is on time, or where you should meet your friends when you arrive it is all possible, and much more besides.

The Statistics

Garmin nüvi 1690

Operating system: Proprietary
Software: City Navigator Europe NT 2010
Map coverage: Western & Eastern Europe
Installation: Pre-installed on internal flash memory (amount N/A)
Additional storage: microSD card
Dimensions: 79x125x19mm
Weight: 174.7g
Display: 4.3"
Additional features: Bluetooth, one year nuLink Live services

DID YOU KNOW? *Cochlear implants work by stimulating auditory nerves in the cochlea*

Electronic hearing

'Bionic ears' restore hearing to the profoundly deaf

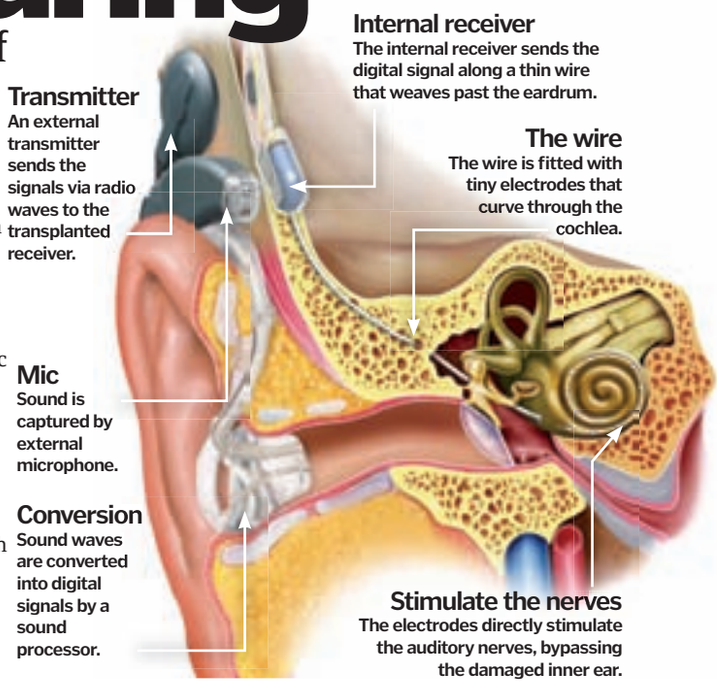
The ear is a miraculous piece of biological circuitry. The outer ear captures sound waves and corrals them to the eardrum, which vibrates subtly with each whisper or bang. The vibrations are captured by three tiny piston-like bones and transmitted to the inner ear, or cochlea, a snail-shaped spiral filled with fluid and hair cells. Fluid waves in the cochlea stimulate the hair cells, which convert the liquid motion into electrical impulses that are sent to the brain via auditory nerves. And that, put simply, is what we call sound.

Unfortunately, even the best evolutionary wiring can short circuit. In cases of nerve deafness – profound hearing loss that strikes both young and old – the hair cells are damaged or missing and sound waves never make it past the cochlea.

In the late Eighties, medical researchers developed the cochlear implant, a radical new technology for 'curing' nerve deafness. The device uses an external microphone and an internal electrode array to transmit digital sound directly to the auditory nerves.

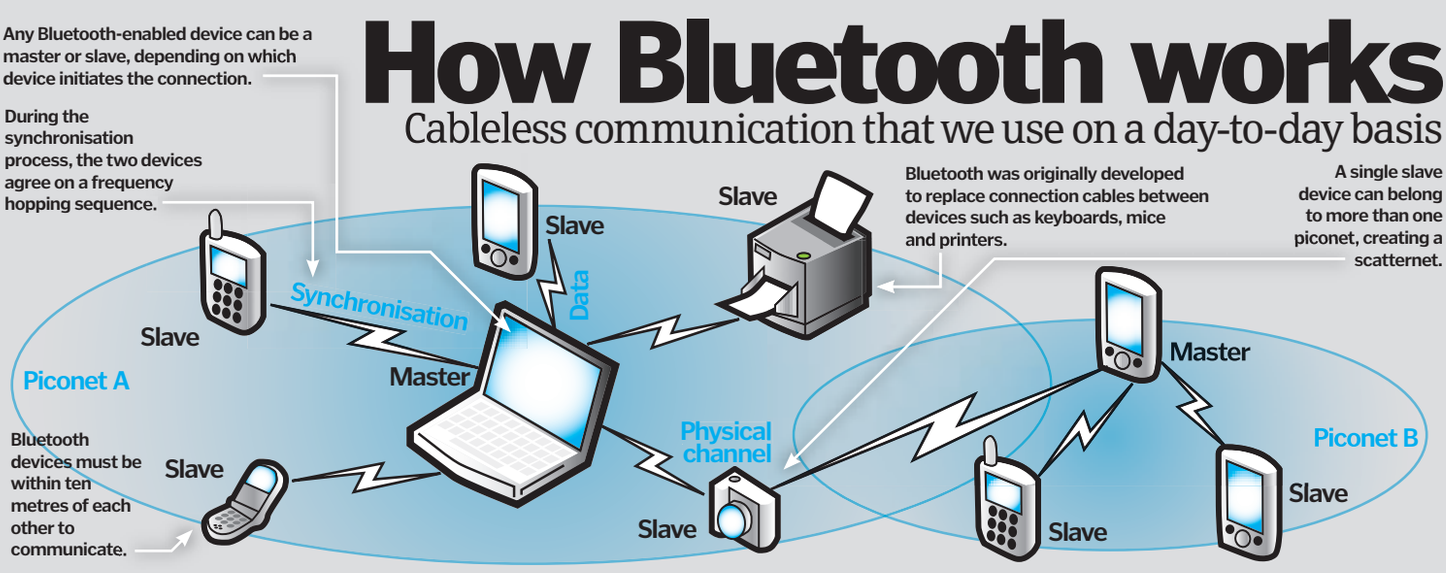
With the cochlear implant, a small disc-shaped receiver is surgically implanted into the bony plate behind and above the ear and a delicate string of electrodes is fed past the eardrum into the spiral of the cochlea. Sound waves captured by a small microphone worn above the ear are sent through a tiny digital processor that converts the sound to electronic impulses. The impulses travel through the skin to the implanted receiver, which sends the signals down the electrode array to the auditory nerves.

While cochlear implants cannot restore normal hearing, they are sensitive enough to replicate both loud and quiet sounds and, with the assistance of speech pathologists and therapists, many formerly deaf patients can learn to communicate without sign language or lip reading.



How Bluetooth works

Cableless communication that we use on a day-to-day basis



Bluetooth has turned our Inspector Gadget fantasies into reality. Cell phones that stream music to the car stereo, open the garage door and call friends hands-free. Fashionable bracelets that vibrate gently to signal an incoming call, stethoscopes that transmit heart and lung readings directly to a laptop and restaurant tables that double as touch-screen menus.

But exactly how does Bluetooth get all of these gadgets to speak the same language? It's all about radio signals. Every Bluetooth-enabled device is equipped with a tiny radio transceiver mounted on a chip. The transceiver has a range of ten metres (33 feet), within which it can communicate with any other Bluetooth-enabled device.

Bluetooth devices are bundled with software that helps two or more gadgets connect and share data. In all Bluetooth relationships there is a 'master' and a 'slave'. The master device initiates communication by sending out a page. If the slave accepts the connection, it synchronises with the master and the two begin an intricate dance called frequency hopping.

Frequency hopping is a method for sending and receiving packets of data with limited interference and tight security. Bluetooth radios can choose from 79 RF channels. Every time a device sends or receives a packet, it switches to a different channel. The master choreographs the dance and the slave keeps in step.

When two or more Bluetooth devices connect, it's called a piconet or a personal area network (PAN). A single device can connect with up to seven other devices within the same piconet, and that same device can join several overlapping piconets at the same time, making the options almost limitless, and what will be developed next really is anyone's guess.

How a lift / elavator works

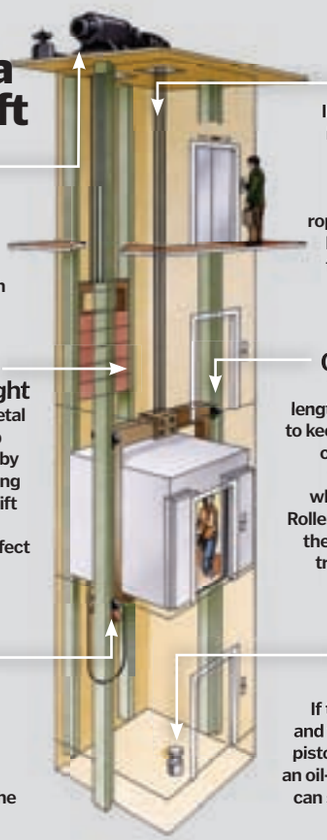
The lift was a world-changing invention because it enabled the creation of today's stunning skyscrapers, not to mention saving an incredible amount of time and effort! Imagine a world with just stairs...

Most modern lifts use a cable system. The lift car runs up and down rails within a shaft, and at the top of the shaft is an electric motor that turns a large wheel, or sheave. Cables run over this, one end of which is attached to the car, the other end to a counterweight.

The counterweight weighs the same as the car plus a typical half load, which means that the two structures balance each other out, so the motor doesn't need to work very hard to move the lift; it just needs to overcome the friction within the system. Of course, the motor must be strong enough to cope with the lift being fully loaded, but this only happens occasionally.

A number of cables are used as back-up in the rare event of one failing. In addition, an automatic brake activates if the lift falls too fast. So those horror-movie scenes of plummeting lifts and flailing cables can never become reality.

Inside a lift shaft



Electric motor
This drives the ropes that are looped around the sheave, which is a grooved pulley system.

Cables
In cable-based lifts, the car is raised and lowered by traction steel ropes. Most lifts have between four and eight cables.

Counterweight
A collection of metal weights that help conserve energy by adding accelerating power when the lift is ascending but have a braking effect when the lift is descending.

Guide rails
These run the length of the shaft to keep the car and counterweight from swaying when in motion. Rollers attached to the car also keep transit smooth.

Braking system
Some lifts have electromagnetic brakes that are activated automatically if the lift loses power.

Shock absorber
If the brakes fail and the car falls, a piston mounted in an oil-filled cylinder can save lives as a last resort.

IBM's Roadrunner

How many processors does it require to compute at the speed of 10,000 PCs?

IBM's Roadrunner supercomputer is currently the fastest on the planet. It's designed to run at 1.7 petaflops although the maximum it has achieved is 1.4. But don't think that's below standard – take a look at how its speed is measured.

FLOPS, which stands for FLoating-point Operations Per Second, is the unit of measurement that governs how much data a computer can crunch, measured by the quantity of a particular kind of sum it can do (a floating-point operation) every second. Your average desktop Mac or PC can do a gigaflop or so – that's about a billion floating point operations a second. To understand the power of the Roadrunner, you need to multiply that by roughly a thousand, and a thousand again – a teraflop is equal to 1,024 gigaflops, and a petaflop is equal to 1,024 teraflops.

The Roadrunner can get nearly 445 megaflops for every watt of power it uses, making it the fourth most energy-efficient computer in the world. This may be thanks to its design: Roadrunner is made out of lots of other computers which have been stripped down to remove non-essentials. Powered by nearly 18,000 processors, Roadrunner is a mixture of IBM's own brand and AMD's dual-core Opteron chips. Despite its sci-fi looks and super speed, much of it is made from off-the-shelf parts. This is what's called a cluster computer – a supercomputer made of other computers – and it's configured in a way known as Triblade: made up of sections comprising two AMD chips and eight IBM ones with 16GB of RAM apiece. The Roadrunner has a total of 3,240 clusters working concurrently, which powers its awesome number-crunching speed.

Noise-cancelling headphones

The way we listen to music has changed dramatically in recent years, making noise-cancelling headphones more important... and expensive

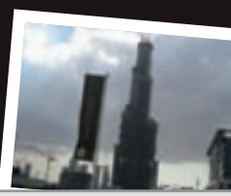
Noise-cancelling technology is not to be confused with noise reducing, although the best examples use a combination of both. Noise reducing – a 'passive' solution that relies on insulating the ears against unwanted sound – tends to be cheaper and applies to both earphones and headphones. Noise cancelling, meanwhile, employs Active Noise Control (ANC) to create sound waves of the opposite frequency to those you wish to block out – also known as anti-noise. This is achieved by positioning tiny microphones close to each earpiece, fast-reacting amplification circuitry to create the anti-noise and a battery for power.

Most studies indicate that ANC is more effective with continuous low-frequency sounds (such as traffic) than rapidly changing mid-frequency ones (such as human conversation) and may also create its own high-frequency hiss. Design-wise they can either sit around or on the ear with prices as high as £400 a pair.

THE STATS BURJ DUBAI

HEIGHT 818m FLOORS **160** FLOOR AREA 334,000m²

ELEVATOR SPEED 40mph AMOUNT OF GLASS **20.7 acres**



The world's tallest building

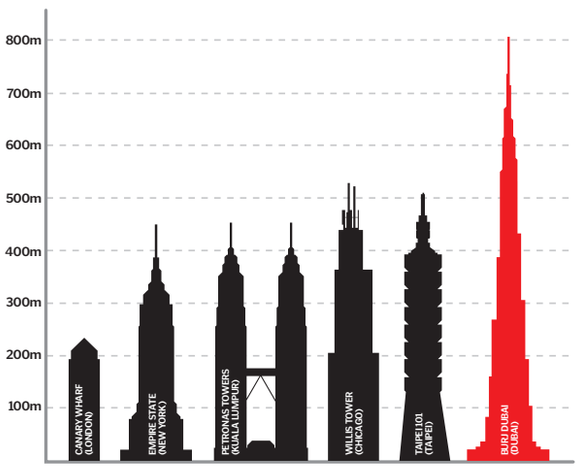
Piercing the sky, Burj Dubai is currently the world's tallest man-made structure

In 2004 construction began on the world's tallest skyscraper. Due to open in December, Burj Dubai is a mammoth feat of human engineering and design. Located in downtown Dubai, the tower forms the eye-catching heart of a huge development venture that has seen investment reaching into the billions of dollars.

As you can imagine, there are major logistical obstacles associated with erecting a mega high-rise tower: it must be lightweight yet resistant to the elements, durable yet aesthetically pleasing, and built to last yet affordable. The Burj tower comprises a mind-blowing 160 floors. Just take a moment to consider the immense weight bearing down on the foundations. So how have the Burj Dubai engineers managed to create a structure so much taller than anything else like it?

Y-shaped foundations, inspired by the hymenocallis plant native to the region, give the building a sturdy base. Parts of the structure are helical in shape with 26 stepped terraces snaking round the outside. The core of the building is hexagonal and surrounded by high-performance reinforced concrete with steel piles sunk 50 metres into the ground. A blend of additives make the concrete heat, fire, and crack resistant. Pumping the concrete to extreme heights before it sets is a major complication, and for the Burj Dubai the builders employed some innovative chilling techniques with the mixture.

Very tall structures generate a massive amount of heat energy, so the Burj required a state-of-the-art cooling system. However, together with high outside humidity, this creates condensation, which must be piped to a tank in the basement. The Burj Dubai's facade is clad with a reflective glass designed to keep the building cool while also allowing plenty of light in. A staggering 20.7 acres of glass have been used for the outer shell of the tower. Of course, you wouldn't take the stairs in a 160-storey skyscraper so a reliable and fast elevator system is essential to any super-tall structure. Like most of the Burj's features, the elevator installation is the tallest in the world, and features double-decker cabs that travel at 40mph.



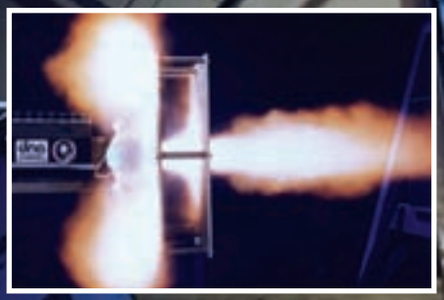
Head to Head SKYSCRAPERS

1. Burj Dubai
Location: Dubai, United Arab Emirates
Height: 818m
Floor count: 160

2. Taipei 101
Location: Taipei, Taiwan
Height: 509m
Floor count: 101

3. Petronas Towers
Location: Kuala Lumpur, Malaysia
Height: 452m
Floor count: 88

All Images © Getty



It could still be years before we see railguns used in combat

The fire power of railguns

Electricity is the secret behind high-tech railguns

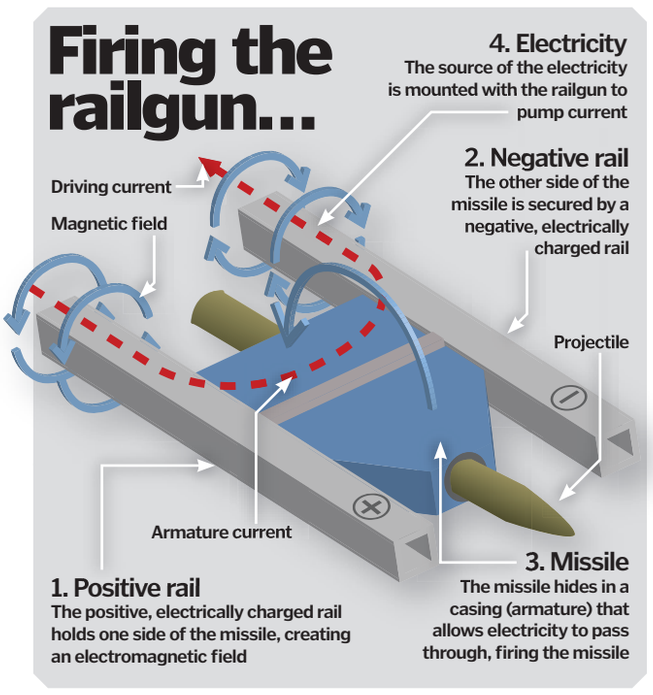
For many centuries gunpowder was the explosive propellant of choice in warfare, partly because there was little else to actually choose from. But modern technology inevitably has evolved, and so had the gun and its ammunition. Careful experiments in the early 20th Century made way for anti-aircraft cannons that harnessed the intense power of electricity, and soon after the railgun was born.

A railgun is made up of two conductive rails (also known as bars), electrical current, and a projectile, for example a rocket or missile. The two rails sandwich the conductive projectile, which is encased in a shell, to make for a complete electrical circuit. Apart from nearly overheating and melting due to the immense amount of friction inside the gun created every time it's fired, a railgun is a groundbreaking step from its former ally, gunpowder.

Ammunition in a railgun is propelled with the help of magnetism. As the electrical current flows through one of the rails it passes through the projectile and onto the opposite rail. One of the rails becomes positively charged and the other becomes negatively charged. This rapidly heating mechanism naturally creates an electromagnetic field. This swirls around both rails holding the projectile, forming an overwhelming power. As the two rails are carrying electrical current in opposite directions the projectile is eventually forced away from the ends of the rails and out of the barrel. The speed all depends on how much current is used and the length of both rails, but can be up to ten times faster than a weapon using gunpowder.

The materials for a railgun have to be highly heat resistant, and they are built to withstand extreme opposing forces made when the projectile is fired. It's also worth considering that the cost of electricity used to power a single railgun is colossal, but could be greatly offset as the cost of otherwise lost bullets is reduced.

The US Navy have test-fired a railgun that fired a projectile at 2,520m/s



MILITARY ROBOTS

Robots fulfil a crucial function in the military, performing tasks too dangerous for soldiers, or working in areas with radioactive or chemical contaminants where humans could not function. The military has access to robots that can deactivate unexploded bombs, sweep for mines, clear hostile and unstable buildings, collect weaponry and patrol the skies.

The Statistics

BEAR

Height: 6ft approx
Upper-body lifting strength: 500lbs

BEAR

Vecna's robot is stronger than your average BEAR

The Vecna BEAR is a sympathetic looking chap. It may look like a teddy bear, possibly to put wounded soldiers at ease, but with a hydraulic upper body capable of carrying up to 500lbs, it is a serious piece of military hardware. Designed to rescue wounded personnel, the BEAR can perform a number of roles on the battlefield, such as inspecting for mines, and collecting arms caches.

The BEAR runs on fire-resistant treads, giving it mobility equivalent to a human soldier. Independent tracks allow it to stand upright, with each limb comprising two tracks fixed in a sort of 'knee' joint. It has a dynamic balance system, which works through a combination of gyroscopes and computerised motors. Power comes through battery cells that are designed to be highly resistant to explosion and fire. It is remote-controlled, supplying the operator with data through cameras and microscopes. Developing the BEAR towards a degree of autonomy is a long-term goal for Vecna.

Robots, named after the hard work they are created to perform, carry an increasing burden in the 21st Century. To perform their tasks robots need to think, to move, to feel, and to produce energy to fuel these activities. Robots have a brain, usually in the form of a microprocessor, though often devices thought of as robots are completely lacking in autonomy, with the real mental processing coming from their operator, who is supplied with data through the robots 'sensory' systems (cameras, microphones etc). Robots move either from a fixed point, or freely through an environment. Mobility is achieved through actuators – devices that take in energy and produce motion. Actuators will use hydraulic, hydrostatic, pneumatic or electrical energy. The robot's legs may resemble humanoid legs, or they may run on tracks. And where humans synthesise ATP (adenosine triphosphate), a robot tends to be fed its energy in the form of electricity, often through battery cells.

The Statistics

SWORDS

Weight: 80-180lbs
TALON attachments:
- Universal disruptor mount
- Thermal cameras
- Magnetic antenna
- Scraper, blade and ski fittings
- Chemical, gas, temperature, and radiation sensors

Weapons the SWORDS can carry:
- Six barrelled 40mm grenade launcher
- Quad 66mm M202A1 FLASH incendiary weapon
- M16 rifle
- 5.56mm SAW M249
- 7.62mm M240 machine gun
- 50 caliber M82 Barrett rifle

Meet the robots that are playing a vital role in military, medical, industrial and research fields

Robots

SWORDS robot

Foster-Miller's SWORDS robots are considered the first robots designed to break Asimov's first law

The SWORDS robots are designed to break Asimov's famous first law of robotics: "a robot may not injure a human being or, through inaction, allow a human being to come to harm".

s2.0

SWORDS robots are controlled remotely from a portable operator control unit. The robots' multiple cameras – offering infrared, thermal and night vision – supply the operator with continuous data allowing them to respond to the robot's environment. Running on tracks the SWORDS can cover rugged terrain; some SWORDS units move as fast as a running soldier. The SWORDS robots can be fitted with automatic weapons, such as the M249, which fires 750 rounds per minute, and a range of sensors and antennas to fit the mission. To fire, the operator identifies the target and the robot electronically aims and fires. The robots are more accurate than human soldiers. Game Boy-style controls with virtual reality goggles are in development for future robots.

X-47B UCAS

Northrop Grumman looks to bring autonomy to aerial combat with the X-47B

The X-47B UCAS is a "transformational, carrier-capable, multi-mission, unmanned combat air vehicle", according to its creators Northrop Grumman. It is essentially a fighter jet that will be capable of intelligence gathering and, Asimov turn in your grave once more, striking hostile targets. The X-47B is designed to be autonomous, allowing it to fly strike missions without input from an on-board pilot or instructions from a remote pilot. The plane is kite-shaped and tailless, with a wingspan of about 28 feet and a similar length.

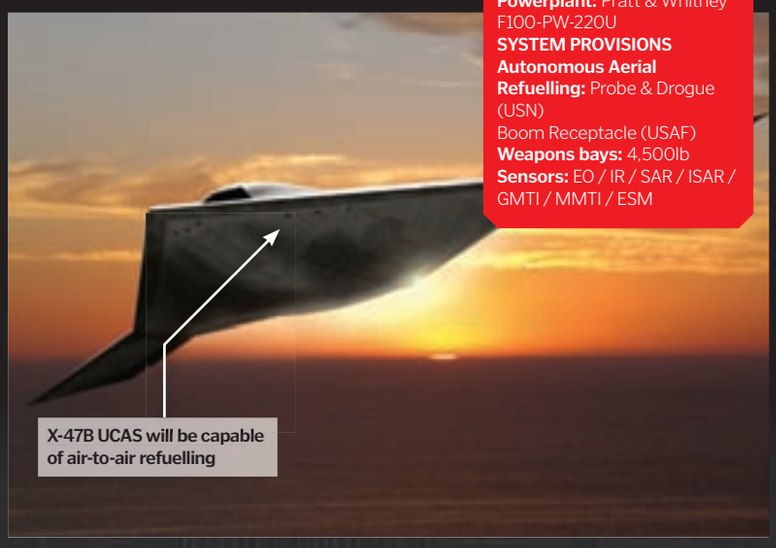
It also has on-board passive and active sensors. The passive sensors feed it radar, heat, pressure (and more) information, while the active sensors probe the environment, conceivably seeking evidence of hostile targets. The X-47B will also be networked to national sensors. The power comes from a turbofan engine, which will produce enough power to propel the X47-B to high subsonic speeds.

A major design problem is how to manoeuvre the plane once on the carrier's deck

The Statistics

X-47B

Wingspan: 62.1ft
Length: 38.2ft
Altitude: 40,000+ft
Range: 3,889+km
Top speed: High subsonic
Powerplant: Pratt & Whitney F100-PW-220U
SYSTEM PROVISIONS
Autonomous Aerial Refuelling: Probe & Drogue (USN)
Boom Receptacle (USAF)
Weapons bays: 4,500lb
Sensors: EO / IR / SAR / ISAR / GMTI / MMTI / ESM



X-47B UCAS will be capable of air-to-air refuelling

Will robots take over the world?

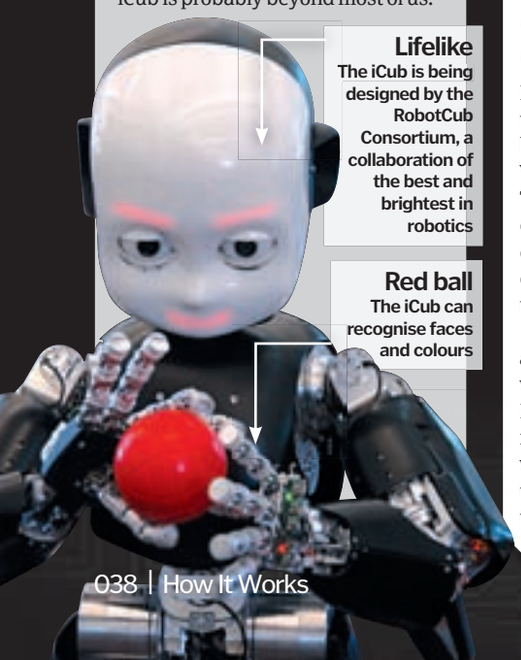
Robots are probably a long way from achieving superiority over their human creators. Humans have a few million years of evolution to thank for their superior adaptability. However, the possibility that computers will one day surpass humans in intelligence is openly discussed by the scientific community. This point is labelled "the singularity" by computer scientist Vernor Vinge. Vinge predicts that the "human era will be ended" if the singularity were to be reached. It is thought that reaching the singularity will be hastened when smart robots are able to develop smarter robots still, in what would amount to robot reproduction. The idea that robots will eventually inherit the earth may be far-fetched, but as robots become more sophisticated a less fantastical fear is that criminals will find ways to exploit them. A SWORDS robot or an X-47B UCAS in the wrong hands with the wrong instructions might be unlikely to take over the world, but it could do some serious damage.

RESEARCH ROBOTS

The human brain contains billions of neurones, firing almost instantaneous signals across a vast landscape. Understanding how human intelligence emerges is something robotics hopes to shed light on. Robots are being used to provide insights into many aspects of animal behaviour – by programming robots to behave in certain ways, scientists can better understand how biological systems function.

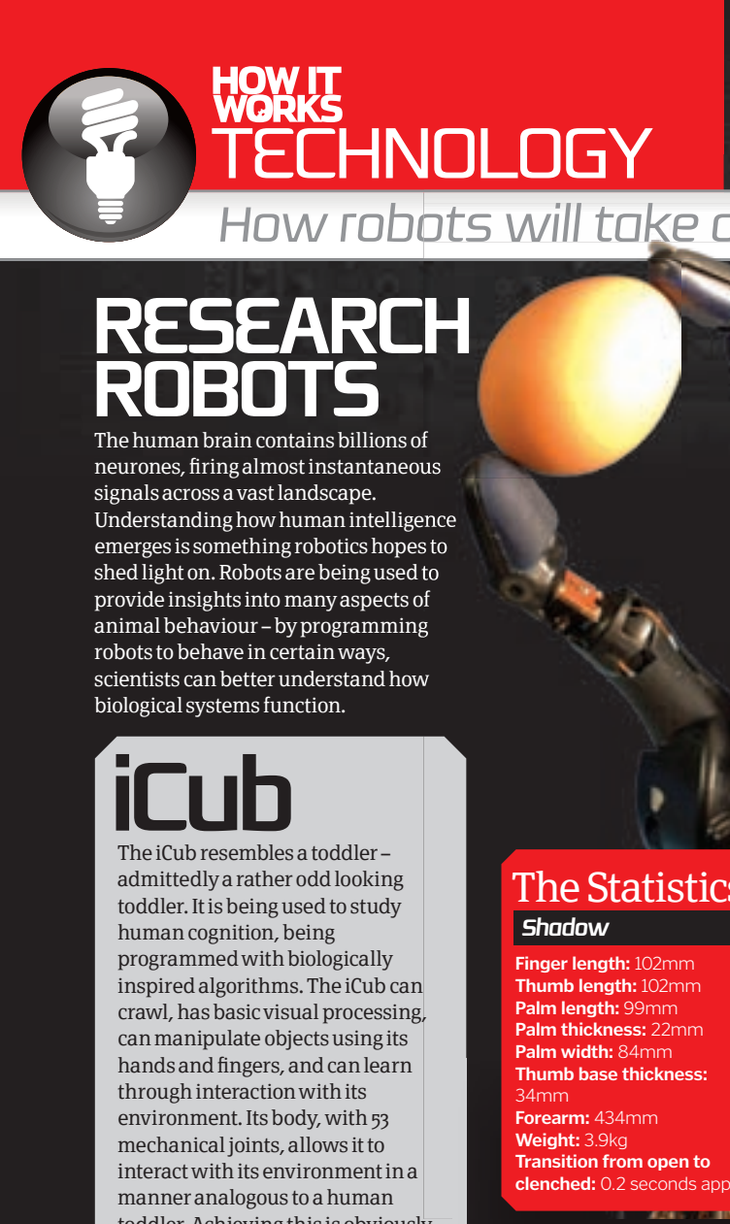
iCub

The iCub resembles a toddler – admittedly a rather odd looking toddler. It is being used to study human cognition, being programmed with biologically inspired algorithms. The iCub can crawl, has basic visual processing, can manipulate objects using its hands and fingers, and can learn through interaction with its environment. Its body, with 53 mechanical joints, allows it to interact with its environment in a manner analogous to a human toddler. Achieving this is obviously very difficult; for example, its waist needs to allow for pitch, roll and yaw in the upper body within specific ranges. Sensors in the limbs give the iCub what we would call proprioception in humans: a sense of your body's position in space. The information on building an iCub is available on the internet, but costing upwards of €200,000, building an iCub is probably beyond most of us.



Lifelike
The iCub is being designed by the RobotCub Consortium, a collaboration of the best and brightest in robotics

Red ball
The iCub can recognise faces and colours



Speed
The hand moves at about half the speed of a human hand

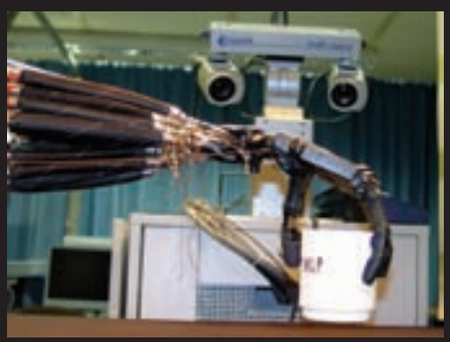
All in the air...
The hand uses air muscle technology, needing electric current and a source of compressed air

Give Shadow a hand

The perfect replica of your grubby paw

The Shadow Dextrous Hand is a faithful reproduction of the average male hand. Pneumatic actuators allow for 24 movements that mirror the degrees of freedom of the human hand. Twenty motors, situated below the wrist, power the movement in 40 air muscle actuators in the hand. Again mimicking the biological hand, the Shadow Dextrous Hand has a pair of tendons coupling every motor. The hand's sensors feed back information about the pressure being applied by these tendons, allowing the hand to grip objects appropriately. Heat sensors prevent the motors from overheating.

Other sensors in the hand provide data on joint position, including the angle of the joints. The hand's movements are controlled through on-board microchips and it can be configured remotely using a PC. Built from metals and plastics, the hand is being used for research into grasping, manipulation, neural control, and the handling of hazardous substances.



The Statistics

Shadow

Finger length: 102mm
Thumb length: 102mm
Palm length: 99mm
Palm thickness: 22mm
Palm width: 84mm
Thumb base thickness: 34mm
Forearm: 434mm
Weight: 3.9kg
Transition from open to clenched: 0.2 seconds approx

MEDICAL ROBOTS

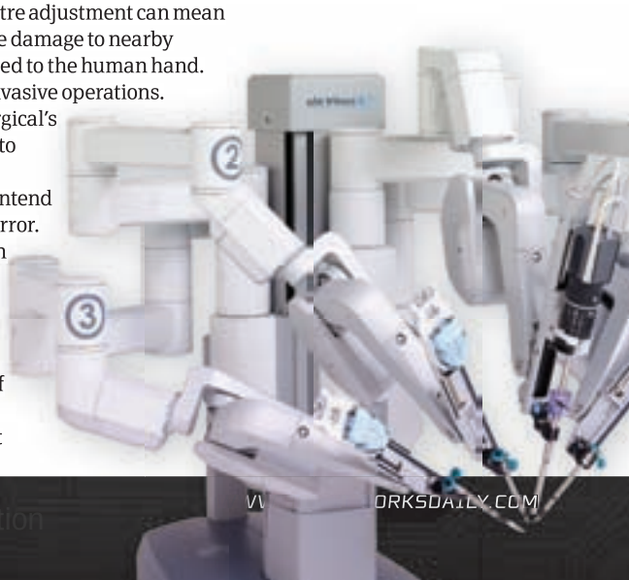
Robotic surgeons can perform operations making smaller incisions than a human surgeon. Such robots are used to perform heart surgery and can be operated remotely by a human surgeon. Robots are used in training to prepare doctors for surgery on human patients and medicine-dispensing robots are eliminating human error in pharmacies.

Robotic surgery adds precision

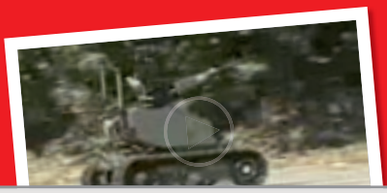
How robots help surgeons plan and carry out complex procedures

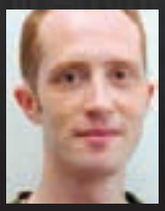
Precision is important – especially in surgery. A one millimetre adjustment can mean the difference between repairing a wound and causing more damage to nearby blood vessels. For the past millennium, nothing has compared to the human hand. Yet new surgical robots help surgeons perform minimally invasive operations. The most common models in use today, such as Intuitive Surgical's da Vinci Surgical System and the ROBODOC, allow surgeons to control needles and scalpels. Most importantly for complex operations, the surgeons can plan which manoeuvres they intend to do and then carry out that procedure with little room for error.

Surgical robots have multiple joints that look like a human arm, controlled by a motor and an encoder. The encoder is what determines the position of the joints and robotic arm. In some cases, a surgeon controls the arm from another room using a video feed that shows the precise location, which is called telesurgery. "A computer knows the design of the robot, knows the precise angle of each joint and where the surgical tool is positioned, so to move a tool through a set



See amazing videos of the SWORDS robot in action





Robots: salvation or slavery?

Will we be welcoming robot overlords any time soon?

Hugo Elias, software, electronics and mechanical design engineer at the Shadow Robot Company, the brains behind the Shadow Dextrous Hand, knows a thing or two about autonomous robots. Inspired by *Terminator Salvation*, out on DVD this November, we asked him whether the *Terminator* future, in which robots attempt to eradicate mankind, could ever become a reality.

HIW: In the *Terminator* series of films robots seek to destroy the human race – could you imagine a future where robots would pose a threat to human survival?
Hugo Elias: I could imagine such a future. In fact, I think I've seen a film where that happens. However, I think it's quite unlikely. Remember that robots are products, manufactured by companies and purchased by other companies or consumers who can't be bothered to do their own hoovering. Robots will be made to do specific tasks, or run applications, like a computer. Just because they might one day look a bit like humans, doesn't mean they will behave like humans. Nobody fears their iPhone trying to destroy the human race, or even becoming intelligent enough to do so. If I purchased a robot from Argos or somewhere, and it tried to take over my house, I'd call up the manufacturer and complain. Then they would issue a product recall: "It has come to our attention that some T-1000 models may, in extremely rare circumstances, exhibit faulty behaviour. Please download and install the new firmware patch issued today."

The most likely way that robots might pose a threat is because of other humans. One country might build an army of robots to attack another country. Which countries have the manufacturing capability to build an army of robots big enough to threaten the human race? Maybe China. But why would they? They have a billion people. Why use robots?

But to pose a genuine threat to human survival? Don't forget there are about 7 billion humans, and every one of us is born from an unbroken line of other humans, every single one of whom managed to survive until breeding age, and managed to breed. That's a pretty good pedigree. Humans are born to survive. We're crafty, resilient, cunning and creative. Robots would have a very hard time conquering us.

HIW: The *Terminator* robots possess intelligence commensurate to, or even superior to, humans – is this an achievable goal, and if so, how far off is it?
HE: Computer power is doubling roughly every 1.5 years, meaning that any amount of computer power you can imagine is not far off. For example, in 15 years, your iPhone or desktop computer will be ten times as powerful. In 30 years, 100 times as powerful. But the questions is, given the raw computing power, will we be able to program them to behave intelligently. The answer is probably yes, by making systems which can learn for themselves.

HIW: The T-800 Model 101 Terminator of *Terminator Salvation* possesses many human faculties, but seems to lack any emotional characteristics – do you think emotional responses and a sense of self-awareness is an achievable goal in robotics?
HE: Responses which appear emotional are already a reality, for example a Japanese robot, Kismet, can have emotional-looking interactions with humans. I think emotional-looking responses will become increasingly important for the general public to accept robots in their homes, and even more so as we need to have extended conversations with them. At the very least, it would be nice to be able to tell if the robot is understanding what I'm saying, or if it's confused.

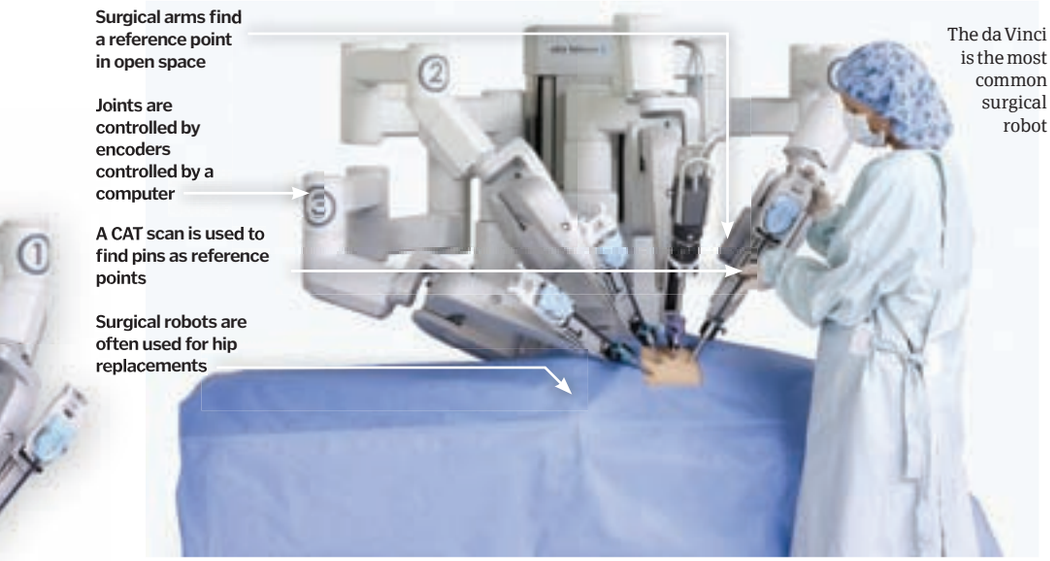
HIW: If robots can think and feel then to what extent would you consider them alive, and worthy of rights?
HE: That's a very difficult question indeed. We can't even agree whether animals can think and feel, despite being almost identical to us. I think it will be a very long time before it's generally accepted that a machine has any kind of feelings worth fighting for.

Having said that, people are often willing to ascribe feelings to simple robots on the basis of their behaviour. For example, I have heard people say "It wants to crawl up my leg".

path, it is partly the surgeon determining the movement and partly the telesurgical robot," says Russell Taylor, a professor and engineering director at Johns Hopkins University.

Taylor says that in some cases, the surgeon actually programs out how a surgical robot will physically perform a task. With these procedures, more common with prostate cancer surgery and hip replacements where it is difficult to reach the area in question, a surgeon might first insert metal pins as markers in the patient, take a CAT scan, and then the robot will use the CAT scan as a reference point for surgical procedures.

One of the most significant challenges in robotic surgery is in determining where the surgical arm is in open space, so the pins provide a virtual reference (the CAT scan) and a physical reference (the actual pins).



The da Vinci is the most common surgical robot

Terminator Salvation is out now on Blu-ray and DVD, courtesy of Sony Pictures Home Entertainment.

This month in **Transport**

Road, rail, air and extreme vehicles get equal measure this issue. We also look into the future of air travel by unravelling the mystery of jetpacks and the foldaway plane. Plus you don't want to miss the feature on the Airbus A380, the largest passenger jet currently flying the skies. And if all that's not enough to quench your desires, there's much, much more.

TRANSPORT

The approaching camel didn't know what hit it...

Abrams M1 in action

Just what makes the Abrams M1 so formidable?

Long-range, 120mm rounds

Benson says a key feature on the M1 is that it fires 120mm rounds up to 4,000m, a decided advantage on the battlefield. The rounds are made of high-density steel, travel one mile per second, and weigh around 30 pounds. "It's like firing a big nail," says Benson.

Heavy armour protection

Both Peck and Benson said another key advantage is that the tank is heavily armoured. Peck says he has never seen a tank that came back for repairs with any noticeable dents; many have fought in multiple campaigns and are still in prime condition.

High-torque engine

According to Benson, the high-torque engine on the M1 is extremely advanced: it uses a form of jet fuel and produces so much energy that, even at 74 tons, the tank can reach speeds approaching 45 miles per hour.

Abrams M1 Battletank

74-ton, 1,500-horsepower behemoth fires long-range cannons

Imagine driving one of these on your morning commute. The M1 Abrams tank, used throughout the Eighties and Nineties for both Gulf wars, and still more advanced than any other tank on the planet, is a 74-ton monster that can crash through walls and over terrain.

"The design of this tank is what makes it unique from its first inception," says Mike Peck, the director of business development at General Dynamics, who designs and manufactures the M1. According to Peck, the M1 uses a "combat platform" suspension with a low-to-the-ground chassis with a contoured body that allows the turret to be nestled down lower than other tanks, making the tank about three feet lower to the ground than similar vehicles. In the mid-Nineties, the M1 was updated with all digital components. Peck says it actually has more electronics than an F16 fighter.

Kevin Benson, a retired Lt Colonel who commanded entire battalions of M1 tanks, says the main advantage of the M1 is that it can fire 150mm rounds up to 3,000-4,000m whereas other tanks – especially those used by Iraqi forces in Operation Desert Storm – could only fire about 1,500m. In that campaign, US forces would surround the Iraqi tanks, safely out of range but well within the range of the M1. Peck says the M1 has a forward-range infrared sensor that works in day or night for long-range shots.

The engine on the M1 is also unique. It uses a turbine engine running at 1,500 horsepower, providing a distinct advantage: because the tank has such a high torque in the engine, it is almost unstoppable on the battlefield. "The engine has the most dense horsepower-per-weight ratio we could find," says Peck.

The M1 also has a pulse jet air cleaner to remove sand and other hazards, which Peck says has doubled the life of the engine. The tank is also outfitted with a 50 calliper coaxial machine gun that can turn 360-degrees, an aid for urban warfare. The M1 Abrams cruises at a top speed of 45 miles per hour on paved roads or 35 miles per hour over sand.

A US tank provides suppressive counter fire in Fallujah, Iraq

THE STATS M1 TANK

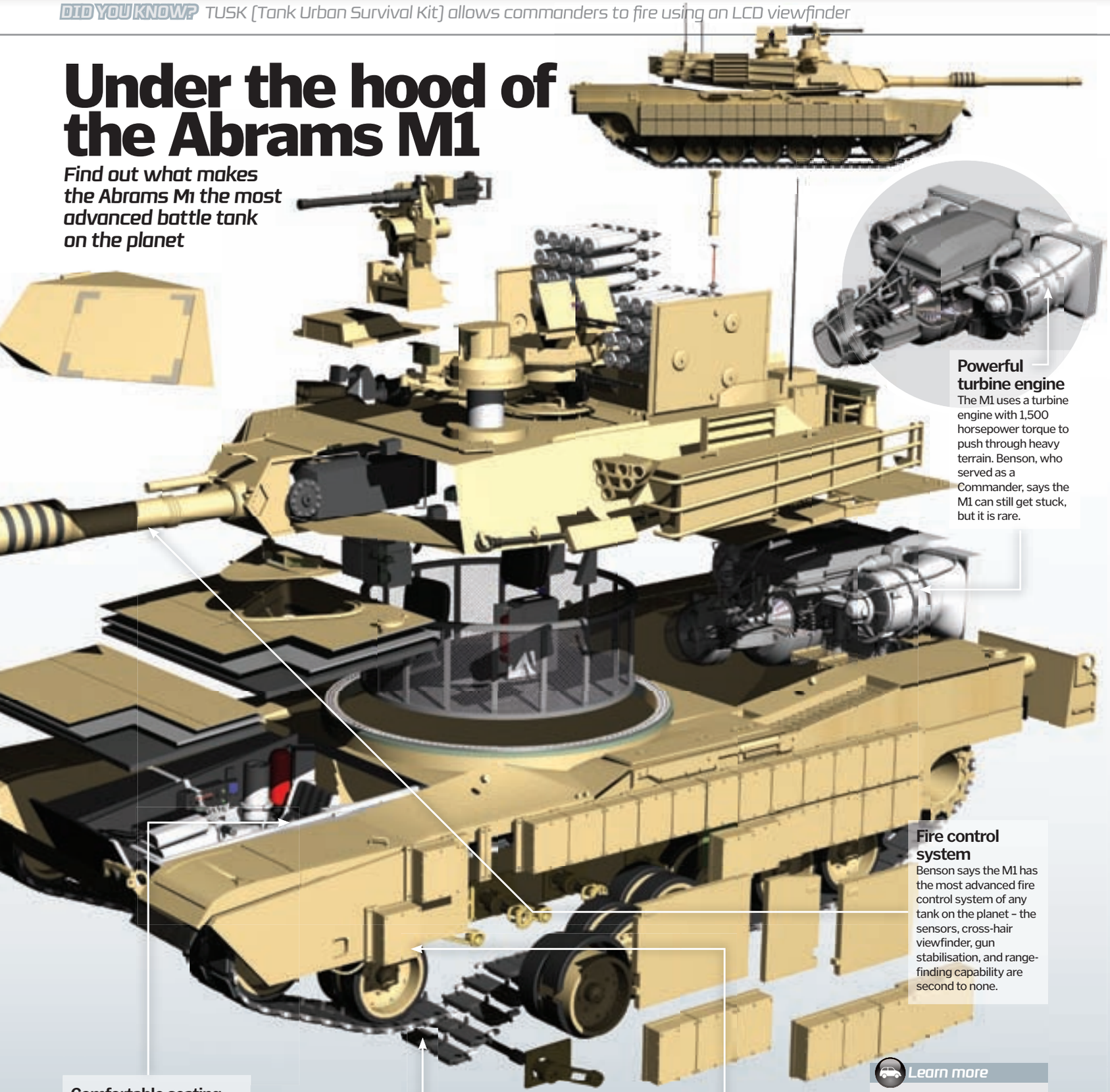
GUN RANGE 4,000m ROUND LENGTH **120mm** TRACK WEIGHT 2 tons

WEIGHT **74 tons** ROUND WEIGHT 30lbs FIRST ENTERED SERVICE **1980**

DID YOU KNOW? *TUSK (Tank Urban Survival Kit) allows commanders to fire using an LCD viewfinder*

Under the hood of the Abrams M1

Find out what makes the Abrams M1 the most advanced battle tank on the planet



Powerful turbine engine

The M1 uses a turbine engine with 1,500 horsepower torque to push through heavy terrain. Benson, who served as a Commander, says the M1 can still get stuck, but it is rare.

Fire control system

Benson says the M1 has the most advanced fire control system of any tank on the planet – the sensors, cross-hair viewfinder, gun stabilisation, and range-finding capability are second to none.

Comfortable seating

The M1 drives like a car – it has a steering wheel and foot pedals, says Benson (some models use levers for forward and back). Peck says he knows of a gunner who sat comfortably during a Baghdad campaign for 75 hours straight.

Two-ton tracks

The heavy tracks that propel the tank are made of a hard rubber with steel pins that hold it all together. Benson says the soldiers in the tank know how to quickly fix any track problems on the battlefield.

Chassis

The chassis of the M1 is what makes the tank able to withstand abuse. Peck says M1 tanks can go through a re-build process three or four times, adding new digital components.

Learn more

For more information about the M1 Abrams tank visit **www.army-technology.com** where you can read more about this destructive behemoth, as well as other lethal weapons used in 21st Century combat.

Illustrations © Alex Pang

Jetpacks explained

Strap a jet engine to your back and zoom off into the sunset. Maybe...

The first flight of the Martin Jetpack

We've seen them in the movies and even for real at the occasional spectacular public event but, for the most part, the dream of jetpacks being the ultimate in personal transport has evaded us.

That's because, although the idea is fun, in practice there are some serious problems. Not least the fact that strapping on a rocket engine and launching yourself into the air at high speed is, well, rather dangerous!

The first experiments with jetpacks were made in the Forties but it was soon discovered that the limitations were such that there has been little serious development since.

Today, most jetpacks use twin rockets powered by hydrogen peroxide, which is combined with liquid nitrogen and a silver catalyst. The reaction is a massive 5,000-times increase in volume in a fraction of a second, which creates superheated steam. This fires out of the jets at over 700 degrees Celsius – another reason these devices are dangerous! Would you want that sort of heat behind your back? The good news is the fuel won't accidentally explode but it is extremely expensive.

The power created is incredible at around 800bhp. But only for about 30 seconds – by which time the small amount of fuel the wearer is able carry will be exhausted. In that short time, though, the jetpack will accelerate very quickly up to 80mph, after which the pilot must ease off the power to ensure he has enough fuel to land safely, otherwise he'll plummet back to earth. Unfortunately, a parachute would be of no help because he won't be far enough off the ground.

What's more, controlling a jetpack is very difficult, as the combination of human, fuel tanks and rocket engines is not a stable or aerodynamic package. For that reason, most pilots are tethered to the ground.

So, as great as they sound in principle, jetpacks aren't a practical form of transport and aren't likely to be for the foreseeable future.

Images courtesy of ICON Aircraft

The Statistics

ICON A5

Wingspan: 34 feet
Length: 22 feet
Height: 7.1 feet
Weight: 1430lb
Top speed: 120mph
Range: 335 miles
Number of seats: 2
Luggage capacity: 60lb
Price: US$139,000 (estimate)

The ICON A5 foldaway plane

The ICON A5 may be a plane but it has a lot in common with a sports car

It's been the stuff of science fiction for years – a personal flying car. Many people have tried to create an aircraft for the masses, but will the American ICON A5 succeed where others have failed? Will we soon all be flying to work?

The ICON is designed to appeal to drivers and, to that end, has a cockpit that looks very like the inside of a sports car – simple, stylish and comfortable. It's also easier to fly than a conventional plane.

It boasts a lightweight carbon fibre fuselage, a 100bhp engine with a propeller facing backwards, and even a huge built-in parachute that will glide the plane safely to earth in the event of an emergency.

The ICON can take off from a runway, using a retractable undercarriage, or from water, and it can do so in just 750 feet. What's more, the wings fold up in minutes so you can tow it behind your car and, if you have room, store it at your home.

FAQ

SO IF I BOUGHT ONE, COULD I FLY IT TO WORK?

New US regulations allow for Sport Flying – a new, easy-to-obtain category of pilot's licence for recreational flying, which you can gain after 20 hours of training. However, pilots are then limited to flying in daylight, with good weather and in uncongested airspace. All of which limits the use of the ICON A5 to fun flying, rather than commuting. Sadly, there's no similar licence available for UK pilots.

James Bond eat your heart out

Autopilot

An autopilot not only gives a pilot a well-earned rest, it can even fly the plane better than a human!

Invented as far back as the early 20th Century, autopilots have transformed pilots' lives and ensure that today's long-haul flights are safe and efficient. An autopilot can control part or all of an aircraft's control surfaces – elevators, rudder and ailerons. The simplest method controls just the ailerons to ensure the plane remains level and gives the pilot less to worry about, while more complex three-axis autopilots take over the control of all three, and will effectively fly the plane.

Modern autopilots are computer-controlled and rely on sensors that monitor the plane's speed, altitude, position, direction, pitch, yaw and roll. These sensors feed information to the computer and, if the plane deviates from its pre-programmed path, the system adjusts the necessary control surface, using servo motors or hydraulic actuators. Some systems also control the plane's engines. GPS can be used to maintain the plane on a set course.

An autopilot will monitor and make multiple adjustments constantly and more effectively than a human, therefore ensuring that the aircraft flies smoothly and efficiently. However, if a failure does occurs, the systems are designed so that the pilot can override the autopilot at any time and take control of the plane.

Some autopilots on modern airliners can even control the take-off, ascent and subsequent decent and landing of the plane, even when visibility is poor. They use a system called autoland, which many of the world's major airports have adopted. On landing, for instance, the plane homes in on an array of radio beacons positioned on the runway and the autopilot will make the necessary adjustments for a smooth landing, with the pilot overseeing what's going on.

"You could imagine a day when planes will fly themselves"

Ironically, such is the success of these systems, there is more chance of an accident in fog while the aircraft is taxiing than actually during take-off and landing. That's why the next generation of autopilot will even be able to direct the plane around the airport.

With such sophistication, you could imagine a day when planes won't need a pilot on board at all. That's not likely in the near future, though, as a human is still required in case the autopilot fails. And besides, you need someone to make annoying announcements just as you're about to fall asleep on that long-haul flight!

Sadly a shade of hovercraft camouflage hasn't been invented yet...

How hovercrafts work

The hovercraft floats on air and is just at home travelling over water as over land

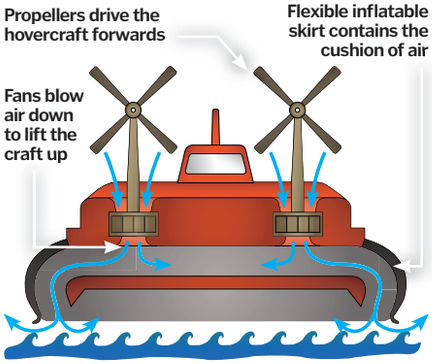
When Sir Christopher Cockerell's invention, the SR-N1, crossed the English Channel in 1959, it was the stuff of science fiction. This futuristic craft was neither boat nor aircraft but rather a mixture of the two. It glided gracefully over land and then slipped onto the water, where it sped along in a cloud of spray. The hovercraft was born.

Cockerell had experimented for years to prove his idea would work, and today's hovercraft works on exactly the same principle. Namely, a cushion of air separates the craft from the ground or water below, therefore reducing resistance to a minimum. The cushion is created by one or more fans blowing air downwards. The first hovercraft struggled to rise off the ground because this air was escaping from around the sides of the craft, so a skirt was added to trap the air underneath, creating a plenum chamber.

The skirt is usually made from flexible fabric or rubber so that it can adjust its shape to suit the terrain, and will also collapse to allow the craft to drop to the ground when the engine is turned off. Modern hovercrafts have a double-walled skirt which is inflated by the air from the fans. Some even have lots of small inflatable 'fingers' to improve flexibility.

To make the hovercraft move forwards, either some of the air from the fan is ducted back to provide thrust, or there is a propeller (or propellers) facing backwards. This may be powered by the same engine as the fan, or by its own dedicated motor. Steering is achieved either by a rudder behind the propeller or by rotating the propeller from side to side. Alternatively, in the case of small hovercraft, the pilot steers simply by moving his weight from one side to the other! A hovercraft doesn't have brakes, so it has to glide gently to a halt.

Even today, watching a hovercraft in action is exciting and just a little unreal.

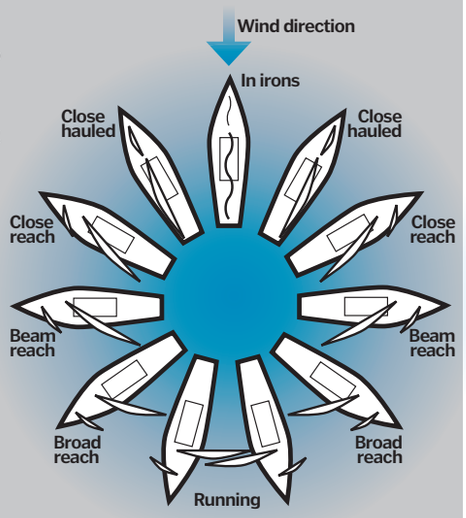


The science of sails

It's not all plain sailing...

The wind pushes your sailboat off into the sunset... but what are the magical forces at work? Contrary to the common view that the wind is merely pushing a sail, the actual physics behave more like an aeroplane wing. On the outside of a sail, air molecules build up and create low pressure area, on the inside there are fewer molecules. This follows the Bernoulli principal, which says kinetic energy builds up when there is unrestricted airflow, in this case when the inside of the sail puts pressure on the outside.

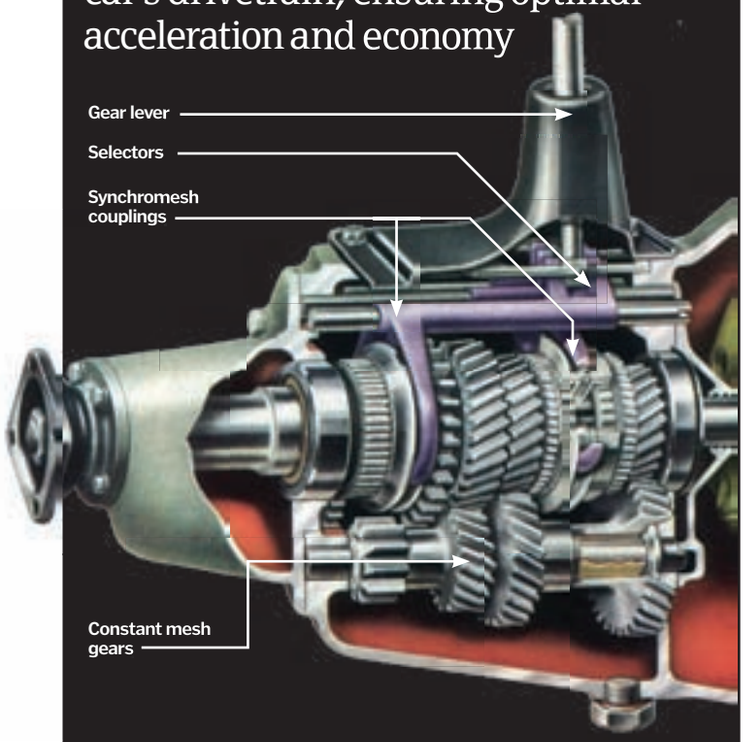
"The sail generates lift, but it is not precisely forward but out to the side," says Tom Lochhaas from sailing.about.com. "It's the keel of the boat that permits forward motion. These two forces – lift and resistance from the keel – produce forward motion."



DID YOU KNOW? *The Jaws of Life are also used to free people trapped in buildings following an earthquake*

Gearboxes

The gearbox is an essential part of a car's drivetrain, ensuring optimal acceleration and economy



You do it without thinking, but each time you change gear in a manual-transmission car, you fundamentally alter the relationship between the engine and the road wheels.

A gearbox is an essential component of a petrol- or diesel-engined vehicle because in order to develop enough power, the engine has to be spinning faster than the wheels are turning. For instance, let's say the engine needs to run at 4,000 revolutions per minute (rpm) to drive the car at 70mph, at which speed the wheels will, typically, only be turning at 1,000rpm. In other words, the output from the engine must be slowed down.

This is done with gears, which are basically toothed wheels that mesh with each other. If you have two gearwheels, one twice the diameter of the other, each time the small one makes one full rotation, the large one will make just half a turn – it will drive at half the speed. In addition, the torque produced will be doubled.

A car gearbox has an input shaft from the engine (via a clutch which allows the engine and gearbox to be separated) with a small gearwheel that drives a larger one on the layshaft, which has a number of different-sized gearwheels on. When the gearstick is moved, one of these gears will engage in one of a number of wheels on the output shaft that leads to the differential, which contains more gears to slow the output further, and then to the road wheels. Depending on which combination of gears are engaged, the engine will be rotating faster or slower in relation to the road wheels.

In first gear, the engine is turning relatively fast which ensures it has plenty of power to get the car moving. As the vehicle's speed increases, the driver works up through the gears, so that the engine doesn't rev too high. Using a high gear keeps the engine speed low, which saves fuel but does mean that there is less torque available to accelerate or get up a hill, so a lower gear then needs to be selected.

The Jaws of Life

Metal-piercing, door-prising engineering – the Jaws of Life save many lives

Buckled and twisted, car crash victims can become trapped in a metal cage impossible to pull open by hands alone. Under the impact of an accident, only certain tools can do the job of separating steel from steel. The Jaws of Life are a set of tools vital to a fireman's inventory. Where a person is trapped or crushed by a vehicle, fast access to powerful tools can save that person's life.

The name was coined by Hurst Performance Inc, and the Jaws of Life are split into three individual tools: cutters, rams and spreaders. Firemen or rescue workers use these life-saving devices to cut metal in two, prise open twisted doors, and shift and hold objects otherwise too heavy to move. The cutters and spreaders can sometimes be seen as one tool, but are still treated separately.

Hydraulic power is the driving force behind these great tools, proving to be a safe and reliable source. Operated by pistons and special heat and electrical resistant hydraulic fluid, the Jaws of Life can move in either direction by control of a valve.

The cutters of the Jaws of Life are heat-treated steel, and are the teeth of the machinery. They cut metal in half with a single bite and are ideal for detaching car roofs. Spreaders are used to open doors and to ease pressure off of trapped victims. They can open up a gap of 40 inches to create areas large enough for a person to wriggle free. Rams are driving rods that are used to prop up dashboards, or to move a collapsed steering column over a victim's legs. These are specially designed for pushing and pulling large weights and can reach distances of up to five feet.

They can save lives and give victims those vital minutes, which is why they are one of the most important engineering feats of the 21st Century.

The rams open up gaps in crumpled cars | The hydraulic ram itself can extend up to five feet

Ram facts
- 15,708 pounds opening force
- 5 feet extended length
- 3.1 inches in width

The cutters of the Jaws of Life slide through metal | These tubes carry hydraulic fluid

Cutter facts
- 94,000 pounds cutting force
- 9 inches cutter opening
- 41 pounds in weight

The tips of a spreader open gaps of up to 40 inches | Spreaders can change their direction of power

Spreader facts
- 18,900 pounds spreading force
- 12,100 pounds pulling force
- 40 inches opening distance

Maglev technology eliminates the rolling friction that bogs down conventional trains, making them faster, quieter and more efficient

Explained: Maglev trains

Maglev train lines cost more than a billion pounds, but they employ the same forces as a £5 magnet set. Every kid knows that the 'north' ends of bar magnets repel each other, while the 'north' and 'south' ends attract each other. This lets you push or pull one magnet around with another. Maglev technology uses magnetic fields to levitate a train and propel it forward. Three alternative designs use various arrangements of different magnet types.

The only commercial maglev, the German-engineered Transrapid in Shanghai, is powered by electromagnets. An electromagnet is a coil of wire with electric current running through it. Magnetism and electricity are sides of the same coin – any electric current generates a magnetic field, and any fluctuating magnetic field induces an electric current. Running current through a coil of wire generates a strong magnetic field. And switching the direction of the current reverses the polarity of the magnet (eg from 'north' to 'south').

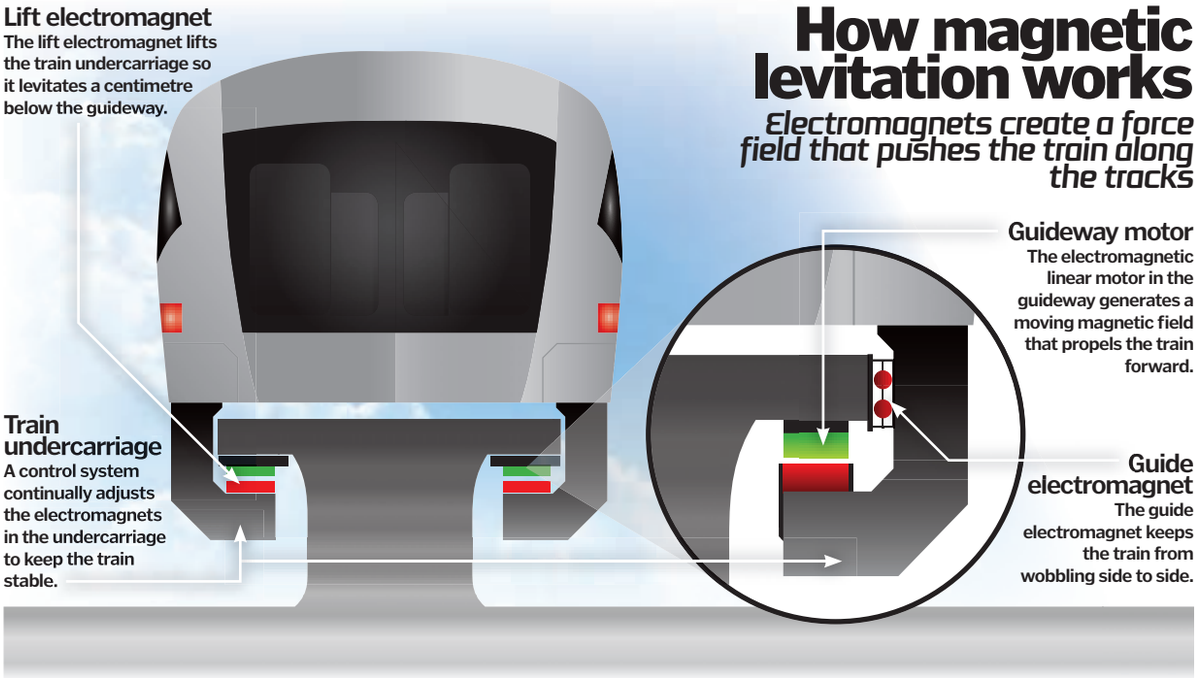
The Transrapid train undercarriage envelopes a T-shaped steel guideway. Inside the guideway, there's an electromagnetic linear motor – essentially a string of coiled wires. Current running through these wires generates a fluctuating magnetic field that travels along the guideway. This magnetic field interacts with the magnetic fields generated by lift electromagnets on the undercarriage of the train, under the guideway. The moving magnetic field pushes and pulls the train along, in the same way two toy magnets move each other.

The lift electromagnets also levitate the train – the magnetic attraction between the electromagnet and the guideway lifts the train up. A feedback control system constantly adjusts the electromagnetic field to keep the train hovering a centimetre above the guideway. Guide electromagnets along the side of the train adjust as well, to keep the train from wobbling.

The Shanghai maglev opened for business in 2004. It runs between the Shanghai financial district and the Shanghai airport, at a top speed of 268mph. An experimental electrodynamic maglev in Japan has reached 361mph. In 2006, a demonstration Transrapid train in Germany collided with maintenance equipment, killing 23 people.

How magnetic levitation works

Electromagnets create a force field that pushes the train along the tracks



Levitation methods

There are three major maglev technologies...

ELECTROMAGNETIC

Electromagnets in the train undercarriage and an electromagnetic linear motor in the guideway generate magnetic forces that interact to levitate and propel the train.

ELECTRODYNAMIC

Superconductor metals kept at super-cool temperatures on the train generate a magnetic field. This induces a separate field in guideway coils, levitating the train. A linear motor in the guideway then propels it.

INDUCTRACK

In this variation on the electrodynamic design, magnets on the train generate a magnetic field. This induces a separate field in passive coils in the guideway, levitating the train.

Learn more

For more information about the Shanghai Maglev Train visit **www.smtdc.com/en/**, where you can view images, watch video of the train in action and learn all about the background of the project, along with interesting facts and figures.

World's biggest car crusher

The world's largest shredder can devour up to 400 scrap cars every hour and at least 85 per cent of the material is then recycled

It's hard to imagine that all those shiny new cars you see in a showroom will, one day, be crushed to death and recycled. But all good things must come to an end, and for many UK cars the end takes place in Newport, Wales, home of the world's largest car shredder.

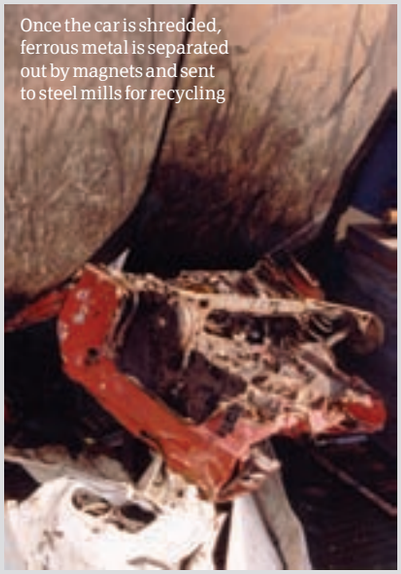
Run by Sims Metal Management, end of life vehicles (ELV) are delivered to the plant by road, rail or sea. The dedicated rail link alone carries over 60,000 tons of scrap to the facility per year, therefore saving over 50,000 lorry journeys.

To begin the process the vehicle is stripped of all its fluids – such as fuel, brake fluid and water – and the tyres and battery are removed. This procedure is called depollution and these items are then sent for recycling elsewhere. The car is then fed into the shredder which is powered by a huge 9,200bhp electric motor. This turns a large 95-ton rotor which literally shreds the entire vehicle into small pieces.

These small pieces are then fed past powerful magnets that remove any ferrous metal (such as iron) and this is loaded onto a ship using a gantry crane that can pack a 30,000-ton ship in 72 hours. It is then sent to steel mills around the world to be reused – perhaps into a new car. Plastics are then separated from the remaining metals using a cyclone method that blows the lighter plastics away from the heavier material.

The non-ferrous metals are sent to a specialist plant where they will be separated into their different types, such as aluminium and copper. The plastics, meanwhile, go to another different plant where they are cleaned up and separated for recycling.

At least 85 per cent of an average family car can be recycled in this way, and Sims currently has plans to increase this figure to an impressive 95 per cent by 2015. The Newport facility has an annual carbon footprint of 242,972 tons – just one per cent of the carbon emissions that are saved by its recycling processes.



Once the car is shredded, ferrous metal is separated out by magnets and sent to steel mills for recycling

The Newport site, opened in 2004, saw Wales become one of Europe's leading recycling centres

The layers of a crash helmet

A life saver underneath it all

The disastrous consequences of your head scrapping across tarmac at any speed is too much to bear, so there has to be careful planning in a crash helmet's design. The success behind a crash helmet consists of multiple shock-absorbing layers, from an outer shell that spreads the impact of a fall, to its inner lining that deforms effectively on impact to protect the head. Material such as intricately woven carbon fibre, along with other strengthening compounds, helps to make a helmet lightweight and strong. There is foam of varying hardness levels, made from polyurethane, on the inside of the helmet to make a crash as comfortable as possible and lessen the impact on the skull. The heat created inside a helmet builds and builds, so with layers comes good ventilation too. Vents strategically placed over the helmet's outer shell allow air to flow in and out to keep you from overheating.

How tyre treads work

Traction and handling are all about the tread

Tyre-building machines spit out 'green tyres' with a completely smooth surface, which would spell disaster on the road. They would have terrible traction and would constantly be aquaplaning – skidding on a layer of water between the tyre and the road. A tyre isn't properly ready for action until it goes through a curing process that moulds a tread pattern into its rubber compound surface.

Tread patterns vary depending on the tyre's intended use, but the basic idea is to offer good traction in a range of conditions, while minimising aquaplaning, vibration and noise. There are several key tread elements that make that happen.

The basic unit of tyre tread is the rib – a raised area going all the way around the tyre, divided by circumferential grooves. Ribs are literally where the rubber meets the road, while grooves prevent aquaplaning. When you drive over a puddle, the grooves give the water somewhere to go, so it doesn't build up between the tread and the road. Ribs may be solid all the way around the tyre, or they may be divided into separate blocks (also called lugs) by transverse grooves (also called slots). One common design includes a solid rib running around the centre of the tyre, with two ribs divided into blocks on either side, and a shoulder at each edge.

Blocks are critical for traction – the edge of each block essentially grabs onto the road. Ribs generally include blocks of different sizes to create a particular sequence that minimises noise. Sipes are smaller horizontal slits within blocks. They give blocks more flexibility and provide additional edges that boost traction, especially in tricky conditions such as snow, ice, and mud. Dimples are smaller indentations that help cool the tyre.


Tyre tread keeps this Porsche on the road, just about...


Continuous tracks took off with the invention of WWI tanks

Caterpillar tracks

Tanks, diggers and snowmobiles would be stuck without their innovative terrain-busting tracks

Named after the Caterpillar company, continuous tracks took off with the invention of the military tank during World War One. Caterpillar tracks can cope much better with rough and muddy terrain than wheels with pneumatic tyres; they are much tougher and spread the weight more evenly.

The track belts are made from a number of identical steel or rubber segments joined by hinges, so that the assembly is flexible, and made into a continuous loop. This loop is wrapped around a row of closely spaced wheels, usually linked to some form of suspension. One or more grooves in the wheels locate with protrusions on the inside of the track to ensure it doesn't slip out of position.

One or more of the wheels – or a dedicated sprocket – is powered by the vehicle's engine and engages with holes in the belt to drive it around the wheels, and therefore move the vehicle forward.

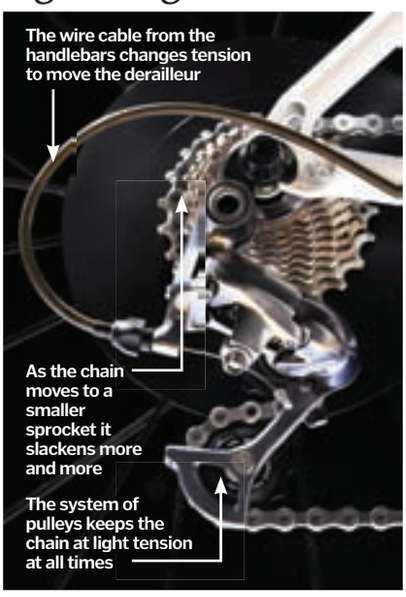
The vehicle is steered by varying the speed – and sometimes direction – of the tracks on each side. To turn right, for instance, the left-hand track turns faster to pull that side of the vehicle forward.

Bike derailleurs

How a modern bicycle gets in gear

We have unspoken trust in bike derailleurs. The front and rear derailleurs change our gears while we pedal hard, and we expect them to work, but what really happens?

The job of derailleurs is more than just changing from gear to gear. The tension of the wire from your handlebars moves the rear derailleur to 'derail' and change sprockets. The second job of the rear derailleur is to reduce slack on the chain. When you change gear to a smaller sprocket, the chain gains slack. The top of the chain is pulled tight as you pedal, and the bottom half is tightened by the rear derailleur. However, the chain is not completely tight so the derailleur can shift sprockets even if you're pedalling hard. The S-shape seen on the rear derailleur is a system of spring-loaded pulleys which automatically take up the slack as the chain shifts sprockets.



"Built in 16 manufacturing sites across Europe, constructing the A380 is a logistical nightmare"

Airbus A

At around $300 million each, it's the largest and most expensive passenger plane in the world. Yet the Airbus A380 is also supposed to be the most fuel efficient, noise reducing and eco-friendly people carrier in its class

The Rolls-Royce manufactured engines will keep the A380 in the sky

At the controls of the world's largest jet

Built in France, Germany, Spain and the UK and assembled in Toulouse, the A380 is a truly pan-European project; an attempt not just to revolutionise long haul flying but aircraft design and construction itself. From the carbon fibre reinforced plastic that makes up roughly 25 per cent of the structure, to its unique wide-body fuselage, the A380 has been designed to set new standards, so much so that even major airports like Heathrow need a multi-million pound refit before they can handle it. With an operating range of 15,200km (enough to fly non-stop from New York to Hong Kong) and a cruising speed of Mach 0.85 (around 560mph), the A380 will open up new routes and possibilities for international travel, but the real breakthrough is in its sheer size and ambition.

Whichever way you look at it, the Airbus A380 is massive. With a wingspan of nearly 262 feet (that's 1 ¾ football pitches) and a maximum takeoff weight of 1.2 million points, it affords 50 per cent more floor space than its nearest rivals. The A380 has many potential configurations, from its maximum passenger capacity of 853 passengers to the current layout of 555 passengers in three classes, still significantly more than the 416 carried by the current long-haul leader, the Boeing 747-400.

But what about claims that this long-haul behemoth is actually environmentally friendly, something many green campaigners maintain is a contradiction in terms? As always, there is truth on both sides. As one of only a handful of commercial aircraft to adhere to stringent ISO 14001 corporate certification, the A380 is at the forefront of environmental aircraft design. With 33 per cent more seats than a 747-400, it carries more passengers while consuming less than three litres of fuel per passenger over 100km, roughly equivalent to a family car and 17 per cent less than a 747. Meanwhile the high-efficiency engines developed by Rolls-Royce, General Electric and Pratt & Whitney produce only about 75g of CO_2 per passenger kilometre, which is also less than a 747 (although Boeing would maintain not less than its own planned successor, the 787 'Dreamliner'). On the other hand, those figures are dependent on flying at near maximum capacity, which few of the A380's initial buyers are expecting for several years.

Meanwhile, environmentalists argue that the combination of the 1.5 million passengers who have already used the A380, the commercial pressure to fill all those extra seats and the airport congestion and urbanisation caused, merely compounds the environmental damage created by any expansion in long haul flying. Either way, people are going to be discussing the pros and cons of this aerial juggernaut for decades to come.

5 TOP FACTS
AIRBUS A380

Bigger not biggest
1 Although the largest passenger airliner, the Ukranian AN-225 Cossack, designed to transport space vehicles, is the biggest plane.

Safety first
2 During safety tests in Hamburg in 2006, 853 passengers and 20 crew managed to evacuate an A380 in 78 seconds.

It should be so lucky
3 The A380 broke with previous Airbus model numbering because eight is considered a lucky number in some Asian countries.

No more jet lag
4 Combining less cabin noise with greater cabin air pressure, the A380 is designed to reduce the effects of travel fatigue.

Fast and furious
5 On 1 December 2005, the Airbus A380 achieved its maximum design speed of Mach 0.96 while performing a shallow dive.

DID YOU KNOW? *The A380 can fly non-stop from New York to Hong Kong*

A380

The luxurious interior can make you forget you're in a plane!

The two-storey cabins can hold up to 853 passengers

The Statistics
Airbus A380

Weight (empty): 610,700lbs
Length: 73m (240ft)
Wingspan: 79.75m (261.8ft)
Maximum number of passengers: 853 (currently configured for a max 555)
Max speed (at cruise altitude): 945km/h, 587mph, 510 knots
Maximum payload : 90,800kg (200,000lbs)

The A380 seen flying over Broughton, where the wings are built

Developing the A380

Although the development of the A3XX series was only formally announced in 1994, it had been on various drawing boards since back in 1988, initially as part of a top secret Ultra High Capacity Airliner project designed to break the dominance of the mighty Boeing 747. During its complex genesis it went through phases of being a joint Very Large Commercial Transport (VLCT) study with Boeing and a revolutionary 'flying wing' design before assuming the oval double-deck form it boasts today. This was finally agreed upon because it was deemed to provide more passenger volume than a traditional single-deck design as proving more cost effective than the VLCT study and Boeing's brand new 787.

Built in 16 manufacturing sites across Europe, constructing the A380 is a logistical nightmare. The front and rear fuselage sections have to be shipped from Hamburg to the UK while the wings are built in Bristol and Broughton and transported by barge to Mostyn. Meanwhile, the belly and tail sections are built in Cádiz and then taken to Bordeaux. Eventually all these parts must be transported by barge, road and rail to Toulouse where the aircraft is pieced together. Along the way, roads need to be widened, cargo ships refitted and barges specially built to accommodate the parts. The finished aircraft must then be flown back to Hamburg for painting and any other finishing touches.

It's not just logistics that have proven problematic. The A380's development coincided first with a financial crisis in the Far East and more recently the global economic downturn, affecting both development cost and potential markets. Originally scheduled to take eight years and $8.8 billion to develop, it has so far cost an estimated $15 billion, with development of the freight version, the A380-800F, first postponed and then suspended. Meanwhile the break-even point for the passenger version, the A380-800, has risen from 270 to over 420 units, of which 200 have been ordered and around 20 delivered, most recently to the Saudi Arabian airline, Saudia. The A380-800 made its maiden flight on 27 April 2005 from Toulouse and its first commercial flight from Singapore to Sydney on 25 October 2007.

This month in **Science**

From the truth about how crime scenes are investigated to the world's largest x-ray generator, this month's science section is filled with amazing knowledge for you to soak up. Ever wanted to know how unwanted buildings are demolished? Look no further, because it's all here in **How It Works**.

SCIENCE

Real-life

We separate the hard facts from the science fiction of TV crime solving

What is it about a semi-decomposed corpse that is guaranteed TV ratings gold? Every week, millions of viewers tune in to watch the intrepid crime scene investigators of the Las Vegas and Miami police departments scamper around a blood-soaked basement in their elastic booties, tweezing out microscopic bits of enigmatic evidence, bagging and tagging puddles of bodily fluids and making more than the occasional bad pun.

We love the *CSI* TV franchise for its Sherlock Holmesian twists, multi-dimensional characters, and yes, the good old-fashioned gore. But how faithful are the show's writers and actors to the real-life business of crime scene investigation? We talked to some CSI experts to see how well Hollywood knows homicide.

Before *CSI* ruled the airwaves, few people knew (or cared) about the dirty and difficult work of crime scene investigation. In real-life CSI, there are two basic kinds of workers: the people who process the crime scene – collecting evidence and documenting every detail – and the folks back at the lab, also known as forensic scientists. Forensic science is any scientific discipline or process used to aid the criminal justice system, like DNA analysis, fingerprint matching or ballistics testing.

One big misconception fuelled by TV is that CSIs are 'investigators' in the classic sense. In reality, CSIs stick to their roles as evidence collectors and lab workers. They don't track down or arrest suspects. If they have a gun – many CSIs are civilians – they would never have the chance to draw it. They use their expertise to aid detectives in their investigations and testify in court concerning the analysis of evidence, but high-speed chases are out of the question.

DID YOU KNOW? *The first police crime lab was set up by Frenchman Edmond Locard in 1910*

e CSI

Living the CSI dream

The old-school way to become a crime scene investigator is to become a cop, hang around a lot of homicide scenes and apply for a CSI position when one becomes available.

If guns and squad cars aren't your thing, you can take the civilian route and get a degree in forensic science or a related field. Because of the huge popularity of the *CSI* TV shows, many colleges and universities now offer degrees in forensic science, forensic chemistry, criminalistics, forensic psychology, forensic biology and forensic anthropology. Your best bet is to have a strong science background, no matter what your major is.

It's important to note that there are tons of specialisations within the forensic sciences that have wildly different requirements. For example, forensic dentists (odontologists) must get their dental degree first, then learn the techniques of identifying and analysing bite marks. Forensic pathologists are fully licensed medical doctors who use their vast anatomical knowledge to conduct autopsies.

Many people get involved in CSI work as a sideline to their regular day job. Engineers, for example, can use their professional expertise to discover whether a building collapsed on its own, or if it was demolished with precision explosives. Even artists can sketch suspect portraits or sculpt facial reconstructions from skeletal remains.

If you're serious about becoming a CSI, contact your police department and find out exactly what they look for in new hires. One thing is for sure: don't expect to get rich. Most CSIs are still cops and are paid according to rank.

Matching evidence to a suspect

When you need to solve a case in an hour (minus commercials), you can't wait around for clunky computers. Just scan the fingerprint, punch a few keys and (bam!) you have a match. Not so fast. While all of the technology on the *CSI* TV shows exists in the real world, a little creative licence really goes a long way.

In the United States, the Integrated Automated Fingerprint Identification System (IAFIS) compares scanned fingerprint evidence with a database of 55 million possible matches. If you're lucky, the system pops out a list of 20 close matches in less than an hour, but queries have been known to linger for days. Either way, it's up to human experts – using physical fingerprint cards and a magnifying eyepiece called a loupe – to make the final call.

For DNA evidence, the process is much slower and much more expensive. A fully staffed forensics lab in a major city can turn around one piece of DNA evidence in a week. The computerised DNA database called CODIS is helpful, but it isn't the magic oracle it's made out to be on TV. CODIS only contains DNA records of convicted felons (over 7 million at last count), so if the police don't already have a suspect, a match is actually borderline miraculous.

Anatomy of a fingerprint

The skin of your fingertips is etched with a unique pattern of tiny ridges. When you touch an object, you leave a nearly invisible stamp of sweat (a blend of amino acids, fatty acids and proteins) called your fingerprint.

To analyse a latent fingerprint – one that's discovered at the crime scene, rather than inked at the police station – CSIs in the US first run the print through the FBI's Integrated Automated Fingerprint Identification System, which compares the print to millions of police records in its national database.

The final evaluation, however, is left to the experts (dactyloscopists), who scrutinise the ridge patterns (arches, whorls and loops) for precisely matching 'points'.

Real-life CSI work is a long way from the glamour of the TV show

CSI: Series 7 is available now on DVD, courtesy of Momentum Pictures Home Ent

Processing a crime scene

A crime scene is a lot like a jigsaw puzzle – a jigsaw puzzle that's been dumped on the floor, fed through a paper shredder, doused with blood and urine and crammed under the couch cushions. The job of a CSI unit isn't to put the puzzle back together, but to find all of the missing pieces.

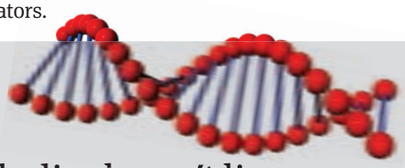
To process a crime scene is to document a crime scene. For this reason, one of the most powerful pieces of technology in the CSI arsenal is a professional quality digital camera. Detectives take pictures of absolutely everything, from macro-views of the entire crime scene to micro-shots of tool marks and fibre samples.

The CSI team must painstakingly scour every inch of the scene for possible evidence. Every drop of blood is photographed, tagged for its location, swiped and saved in a paper evidence bag. Every strand of hair must be tweezed, bagged and tagged as possible DNA evidence. And every fingerprint must be carefully dusted, lifted and photographed.

CSI teams travel with an extensive toolkit of powders, casting polymers, light sources and arcane gadgets for identifying, documenting and preserving physical evidence. Blue-spectrum LED flashlights help illuminate trace amounts of bodily fluids. Electrified sheets of Mylar can lift a shoe print out of the dust. Dental stone is the choice for casting tyre tracks and bite marks.

Once every speck of evidence is fully documented – sometimes hundreds of pieces of evidence from the same scene – CSI detectives look for discernable patterns in the chaos of broken glass, blood splatters and overturned furniture. This 'interpretation' of the crime scene – how the perpetrator moved through the scene, what he touched, in which direction he fled and so on– is highly valuable to investigators.

DNA testing



Guilty or innocent? The double helix doesn't lie

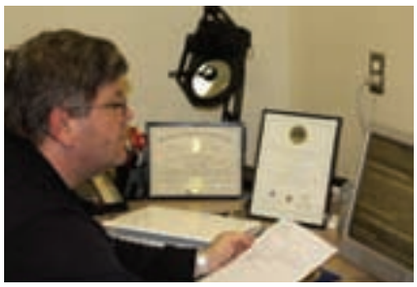
Every single cell in your body contains your unique DNA. For crime scene investigators, this means that even the smallest traces of biological evidence – blood, sweat, skin, hair, saliva, semen, even dandruff or earwax – can be analysed and then matched with any potential suspects.

First, the DNA is isolated and copied using an enzyme called polymerase, creating a much larger sample of DNA molecules for analysis. Then lab technicians compare 13 specific 'loci' on the DNA strand that differ the most between individuals (only 0.10 per cent of our total DNA is different).

If all 13 loci match the DNA sample from a suspect, case closed. Identical twins aside, the odds of having the same DNA as another person are more than one in a billion.

DID YOU KNOW? *DNA can be obtained from fingerprints*

Meet a real CSI



Sergeant Michael Del Cimmuto runs the Mobile Crime Unit for the Pittsburgh, Pennsylvania Police Department. A 20-year veteran of the force, Del Cimmuto oversees a team of 12 CSI detectives and two latent fingerprint examiners. A fan of the *CSI* TV shows, Del Cimmuto is quick to point out that if they made a show about real crime scene processing, it wouldn't last a week.

"People get this idea that we can do these fantastical things," he says, like pop a fingerprint into a computer and it comes back, "Match! Match! Match!" The best that the computer can do is isolate 20 or 30 possible matches from the millions in the database. Then it's up to his latent print examiners to compare every ridge detail by hand. But staring at fingerprint cards for hours makes for bad TV. Even though all of Del Cimmuto's detectives are sworn police officers, they are crime scene experts, not investigators. "One of the guys from my unit would never barge into an interrogation and tell the homicide detective, 'Hold the suspect! I have a few questions,'" says Del Cimmuto. He'd get kicked back to the lab.

The CSIs on TV have the luxury of working one case at a time (and solving it in an hour). In the past nine months, Del Cimmuto's team has processed 2,485 crime scenes, collected 980 fingerprints, tagged 189 firearms, processed 163 vehicles and collected over 11,000 pieces of evidence like shell casings, blood, hair and fibres. The paperwork alone is staggering.

Last are the wardrobe issues. "No $600 sunglasses. No Armani suits," chuckles Del Cimmuto. In fact, the Pittsburgh CSIs had to install a washer and dryer in their unit to deal with uniforms too 'contaminated' to take home.

Testing for blood and sperm

At a crime scene, bodily fluids like blood and sperm are prized evidence. Not only do they contain DNA, but simple blood-typing can greatly narrow down the list of potential suspects. The trick is finding the fluids in a chaotic crime scene.

Urine, semen and saliva are naturally fluorescent, meaning they reflect UV light in a different spectrum. To find trace amounts of bodily fluids, investigators scan the crime scene with handheld black lights or blue LED flashlights while wearing orange goggles that filter out non-fluorescent sources.

Blood, however, doesn't fluoresce, so investigators use a special chemical spray called luminal that glows blue when it reacts with the haemoglobin in blood. If a blood sample is isolated, analysts use a precipitin test to find out if the blood is human or animal. Then they run ABO and Rh tests to determine blood type. In 80 per cent of cases, blood type can be determined from sperm.

Image © Arrowhead Forensics

Forensic toolkit

CASTING SILICONE
A liquid polymer that quickly solidifies to make casts of bite-marks, delicate tool marks and even lift fingerprints. Silicone is sensitive enough to cast the minuscule markings on a dollar bill.

DENTAL STONE
This dental-grade casting material replaced plaster of Paris for recording tyre tracks and shoe prints in mud, dirt or even snow.

LED FLASHLIGHT AND GOGGLES
Intense light in the blue spectrum causes bodily fluids to fluoresce – or reflect back in the orange spectrum. Orange goggles help isolate those reflections to identify trace amounts of semen or saliva. LED lights in other spectrums can help locate hair, fibre and other trace evidence.

LUMINOL
This chemical powder, when mixed with water, can be sprayed all over a crime scene to reveal trace amounts of blood. When luminal reacts with the haemoglobin in blood, it glows blue for up to 30 seconds, a phenomenon known as chemiluminescence.

DIGITAL CAMERA
CSIs use professional cameras with special macro lenses for documenting the most minute details of evidence. They also use rulers and measuring tape for indicating the size of an object.

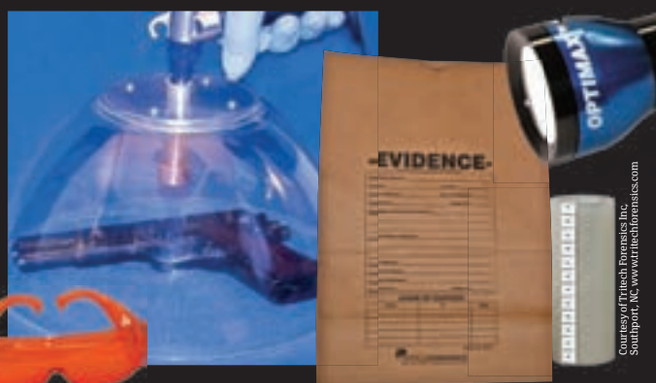
EVIDENCE BAGS
All evidence from a crime scene is stored in paper bags, not plastic. Plastic tends to capture moisture, causing evidence to degrade or grow mould.

FINGERPRINT POWDER
Different coloured powders are used to contrast with the background material. Using a delicate brush, investigators apply small amounts of powder, which sticks to the moisture left by a fingerprint.

TRANSPARENT TAPE
Regular Scotch tape is one of the easiest ways to 'lift' a dusted fingerprint and attach it to a card for photographing.

SUPER GLUE FUMING KIT
Forensics labs are equipped with special fuming chambers where fumes from heated super glue stick to oily fingerprint residue on weapons and other crime scene objects. In the field, CSIs use portable tents or cardboard boxes as chambers and heat the super glue with simple coffee warmers.

ELECTROSTATIC DUST PRINT LIFTER
Investigators place a sheet of Mylar on top of a footprint left on a dusty surface, then run DC current through the Mylar to make the dust stick to the surface where it can be easily photographed.



Courtesy of Tritech Forensics Inc, Southport, NC, www.tritechforensics.com

"All that is left is a two-storey pile of rubble"

Building dem

What it takes to turn solid cement and steel into a waterfall of cascading rubble

Modern building demolition is an exquisitely choreographed dance of destruction. Dynamite-triggered 'implosions' – where a building collapses in on itself just like a crumbling house of cards – are so violently beautiful that they have even become a spectator sport. Demolition junkies are known to camouflage themselves as shrubs just to get a close-up shot of the carnage.

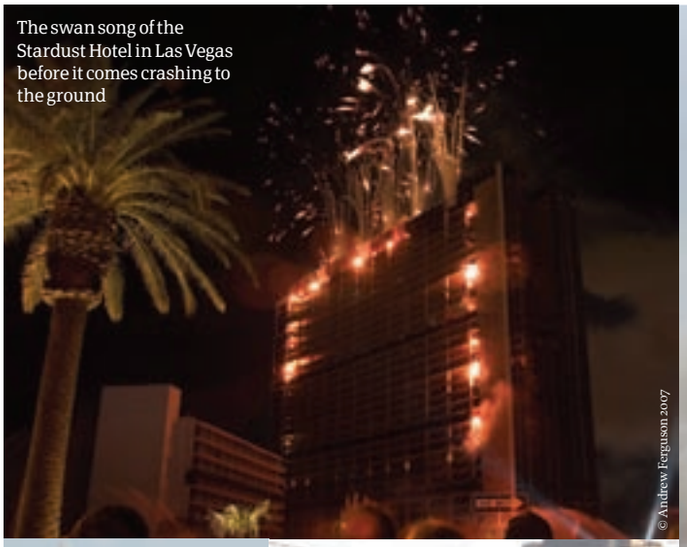
Blowing up a building is easy, minimising damage to nearby structures is the tricky part. There are tumbling walls and flying debris to worry about, not to mention the earthquake-like vibrations produced by millions of tons of crashing cement and steel. The explosives alone can produce high-pressure shockwaves that shatter windows for miles.

Demolition experts are called blasters ('explosives engineer' lacks a certain punch). They know that the most powerful force on a demolition site isn't the thousands of pounds of dynamite, but the incredible potential energy of gravity. The key to minimising damage and softening the impact of 30 stories of rubble is to use the least amount of explosives possible and let gravity pull the building down in a progressive, 'liquid' collapse.

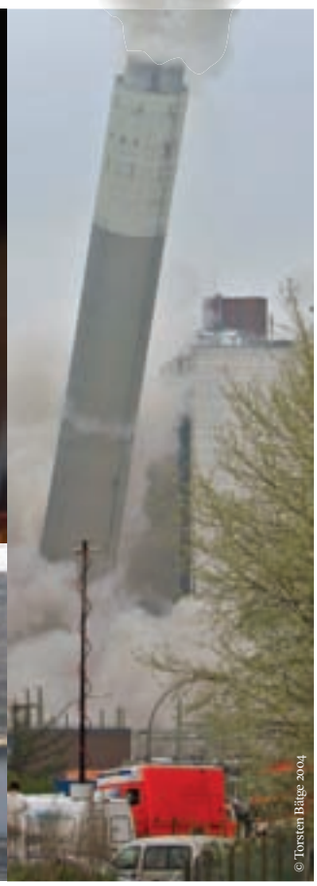
To trigger a progressive collapse, blasters divide the building into separate vertical columns. They drill thousands of holes in the weight-bearing supports under each column and stuff them with dynamite. The supports are wrapped tightly in chain-link fencing and thick plastic fabric to contain flying debris.

Each stick of dynamite is plugged with a blasting cap that controls the precise timing of the explosion. All of the explosives are connected back to a single detonator by miles of detonator cable. When the blaster yells "Fire in the hole!" he activates the detonator, initiating a series of sharp, popping explosions that obliterate the column supports section by section.

The result is breathtaking. Each column seems to melt to the Earth in a smooth, wave-like motion. The fluid collapse sequence minimises vibrations on the ground and the small, delayed explosions reduce the damaging effects of shockwaves. When the dust settles (which can take 15 to 30 minutes), all that is left is a two-storey pile of rubble, neatly contained within the footprint of the original structure.



The swan song of the Stardust Hotel in Las Vegas before it comes crashing to the ground



EXPERT PROFILE:

The Loizeaux family

Expertise: Multi-generational master blasters

For the Loizeaux clan of Maryland, the blasting business is a family business. The late Jack Loizeaux got things started back in the Forties by vaporising tree stumps with dynamite instead of a chain saw. He moved on to topple chimney stacks and small buildings before founding Controlled Demolition, Inc. (CDI), today one of the largest explosive demolition companies in the world.

CDI is now run by Jack's son, Mark, with help from brother Doug, his wife, his two daughters and the occasional daughter's boyfriend. The family has brought down over 7,000 structures and holds world records for imploding the largest building (Seattle Kingdome), the tallest (J.L. Hudson Department Store) and the most buildings in a single sequence (17 apartment buildings in Puerto Rico).

DID YOU KNOW? *After the Seattle Kingdome was demolished in 2000, it was replaced by two separate stadiums*

olition

1. Detonation
Following the explosion the building begins its breathtaking descent

2. Going, going...
Gone. All that is left is a pile of rubble and a cloud of dust

How implosions work

How the charges are placed within a building's structure in order to collapse it in on itself

Kit list

To demolish a ten-storey building you will need:

Conventional demolition equipment: Enough sledgehammers and shovels to gut the bottom floors of non-weight-bearing walls.

Two different kinds of explosives: Regular nitroglycerin-based dynamite for concrete supports and a high-velocity explosive called RDX for slicing through steel beams. In total, around 180kg of explosives.

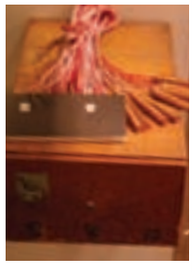
Blasting caps: Thousands of small detonators attached to individual sticks of dynamite to precisely time the detonation.

Hundreds of metres of fencing: And geotextile fabrics to wrap around concrete supports stuffed with dynamite.

Detonating cord: Miles of cable to connect each stick of dynamite to a single detonator control.

Detonator control: Has two buttons, one to charge the electrical detonation and one to fire the explosives.

Years of experience: Blueprints only tell you so much. Expert blasters rely on a storehouse of hands-on knowledge.



How chemicals power batteries

There's a good reason why battery power is called 'juice'

Batteries are everywhere – in your car, your computer and even your cooker. While some are rechargeable and some disposable, they work on the same basic principle.

A battery has two poles labelled + and -. They provide more than a handy guide as to which way up the battery goes in your TV remote. Electrons are produced inside the battery and when it's inert they stay on the negative end. Connect the negative and positive ends with the heads inside a battery compartment and the electrons move to the positive end, producing electrical power.

But where do those electrons come from? The reaction of substances inside the battery produces them. Common elements used are nickel and cadmium, but zinc is also popular. The battery 'plates' are each made up of a different element and when connected they react with the electrolyte paste or 'juice' within the battery, producing electrons. Different substances are used depending on the battery life and power required.

Nickel-cadmium cell

The plates at the end of the battery react with the substance inside

All about acids

From lemon juice to the iron-destroying hydrochloric kind

Acids are chemical compounds that contain one hydrogen atom and an atom from a non-metallic element. Most also contain oxygen. They occur in several forms determined by temperature; prompt pure acids, which are solids, a few as gases but mostly liquids. Those dissolved in water give out hydrogen ion activity greater than pure water, or donate hydrogen ions when reacting with base compounds. This gives acids a pH less than 7.0 on the pH scale, which contributes to the strength of their caustic quality. Chemical reactions can vary greatly in severity, including sour taste, dissolving metals releasing hydrogen gas and corrosive damage to organic material, such as chemical burns.

Acids that produce the most severe reactions are sulphuric, nitric and hydrochloric types. However, the first is a complex and fascinating manufactured compound. Sulphur is burned to produce sulphur dioxide gas. This is heated to 450°C, producing sulphur trioxide. When mixed with water this created the acid compound in question, which is capable of destroying even the hardiest of materials, such as iron.

Sulphuric acid is a highly adaptable compound, mixable with other substances to create completely new products. Mix it with dioxides and you have the ability to purify water, commonly applied at water treatment plants. It's also used for everyday produce: when mixed with wood pulp, fibres bond to create paper. In addition, sulphuric acids are combined with sodiums to help refine petroleum, which is how we create gasoline.

Hydrochloric acid is used heavily in the manufacturing of leather goods, pharmaceutical products, and various household cleaning solutions. It is also used to produce organic compound vinyl chloride, used to in turn produce polyvinyl chloride, or PVC. Many acids can also be found in natural forms, such as lactic acid. Some of these acids help with cell exfoliation, which gently remove dead skin cells and reveals fresh new cells. They also aid in brightening the skin, which is perfect for use on mature skin. Amino acid is referred to as the building blocks of protein, which repair damaged tissue and contributes to the building of cells. Don't forget citric acid. This is a natural preservative and is used to add a sour taste to foods and soft drinks.

The pH scale

pH is a measure of the acidity or basicity of a solution. A strong acid has a pH of one and a strong base has a pH of 14. A pH of seven is neutral. Here is a formulated pH scale up to 14, indicating the acid strength of

pH0	Battery acid, strong hydrofluoric acid
pH1	Hydrochloric acid concealed by stomach lining
pH2	Lemon juice, gastric acid, vinegar
pH3	Grapefruit, orange juice
pH4	Tomato juice
pH5	Soft drinking water, black coffee
pH6	Urine, saliva
pH7	Pure water
pH8	Seawater
pH9	Baking soda
pH10	Milk of magnesia
pH11	Ammonia solution
pH12	Soapy water
pH13	Bleach, oven cleaner
pH14	Liquid drain cleaner

Head to Head ADDICTIVE SUBSTANCES

Nicotine
According to tests by Henningfield and Benowitz, nicotine is the hardest drug to stay off and has the highest number of addicts.

Alcohol
The same tests found that booze addicts had the most severe withdrawal symptoms produced by stopping use of the drug.

Cocaine
Henningfield and Benowitz found that cocaine was the drug that most induced users and addicts to take it again and again.

Why do we get addicted?

And is it all in our head?

The way we use the word addiction has long been a subject of contention. Many talk of addiction in regards to drugs use, eating or gambling, though not all of these would be classified as an addiction if we used purely physiological addiction definitions. Recently, however, scientists and psychologists have put forward that addiction should also be used to describe psychological dependence as well.

Physiologically, addiction is defined as a chronic condition when an individual becomes biologically and physically dependent upon something, often causing a craving or compulsive behaviour through a chemical change inside the individual. The individual will continue to repeat the behaviour even if it is detrimental to their self. Psychologically, the term addiction is used to describe a recurring compulsion to perform a specific behaviour, again, even if this is detrimental.

While physiological addiction is easier to classify and diagnose due to obvious physical withdrawal symptoms if a substance is removed, psychological dependence is much harder to classify due to the fact individuals can be overly interested, even to near obsessive, about a behaviour, and miss it when removed, but not actually be fully addicted and experience physical withdrawal symptoms when the behaviour is stopped. Often the issues with individuals trying to lose an addiction, such as smokers, is the psychological dependence rather than the physical, in that a smoker will miss the physical smoking of the cigarette and associated behaviour or feelings more than the chemical nicotine rush.

The five basic human tastes

Building a map of the tongue

There is general agreement that humans have five basic tastes, although the fifth taste 'primary' has only been recently officially recognised. Sweetness, bitterness, sourness and saltiness were joined by savouriness in 2002. Several other sensations that the tongue can recognise have been identified but are not classified as tastes.

Sweetness is associated primarily with simple carbohydrates – of which sugar is one of the most common. The way sweetness is detected is complex and only recently has the current model of multiple binding sites between the receptors and sweet substance itself been proposed and accepted. A sweet taste infers that the substance is high in energy and studies have shown that newborns in particular, who need a high calorie intake to grow, demonstrate a preference for sugar concentrations sweeter than lactose, which is found in breast milk.

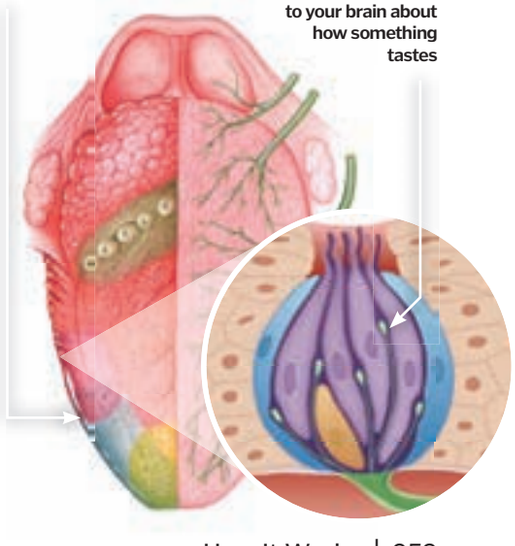
Bitterness can be detected in very low levels and is generally perceived to be an unpleasant or sharp taste. Many toxic substances in nature are known to be bitter and there is an argument proposed by evolutionary scientists that bitterness sensitivity is an evolutionary defence mechanism. Humans, however, have now developed various techniques to make previous inedible bitter substances edible through reducing their toxicity, often through cooking.

The taste of saltiness is produced by the presence of sodium ions, or other closely related alkali metal ions. Potassium and lithium produce a similar taste as they are most closely related to sodium.

Sourness detects acidity. The way we measure the degree of sourness is through rating sour substances against dilute hydrochloric. The mechanism involved in detecting sourness is similar to saltiness in that taste is caused by a concentration of ions – in this case hydrogen ions. Savouriness is the newest of the recognised basic tastes and the taste is produced by fermented or aged foods. Glutamate is a common compound that can cause this taste and consequently savouriness is considered fundamental to Eastern cuisine.

Taste qualities are found in all areas of the tongue, although some regions are more sensitive than others

Your taste buds have very tiny, sensitive hairs called microvilli which send messages to your brain about how something tastes



5 TOP FACTS
TASTE

1 Around 25% of people are 'supertasters'
Supertasters experience taste significantly more intensely than 'normal' people.

2 Other factors contribute to flavour
Factors such as temperature, smell and even hearing alongside taste contribute to flavour.

3 Taste buds are not only on the tongue
As well as having around 8,000 taste buds on your tongue, you also have them on the roof of your mouth and oesophagus.

4 You can lose your sense of taste
If you suffer a head injury, neurological disorders or dental problems, these can severely affect taste.

5 Butterflies taste with their feet
Butterflies' taste sensors are actually located in their feet!

"Biofuels are heralded as pure and easily available"

What are biofuels?

Meet the future fuels that could save the planet

Does the future hold fields of fuel for as far as the eye can see?

5 TOP FACTS BIOFUELS

1 Test of time
Biofuels have been around as long as the automobile, with Henry Ford planning to fuel Model Ts with ethanol.

2 Bioethanol
Bioethanol is an alternative to petrol and can be made from sugar cane, maize or wheat.

3 Detriment
The grain needed to fill a 25-gallon SUV tank with ethanol can feed one person for one whole year.

4 Global issue
Up to 60 million indigenous people are at risk of becoming biofuel refugees.

5 Production
World biofuel production totals about 130 million barrels a year.

Biofuels are heralded as pure and easily available fuels, derived from biomass and biowaste. These combustible fuels are produced from crops, trees, animal waste and now algae, making them far more renewable energy sources than conventional limited fossil fuels such as liquid petroleum. They also promote greater attitudes towards recycling due to their production from waste products, and are environmentally conscious by helping to reduce the amount of greenhouse gasses.

They come in solid, liquid and gaseous forms and are also know as agrofuels. Specific agricultural products are also used to produce biofuels in regions across the globe. The US is responsible for manufacturing switchgrass, soy beans and corn, with Europe contributing to the stock of sugar beet and wheat while Brazil produces sugar cane, China cassava and sorghum, southeast Asia produces miscanthus and palm oil, while India produces jatropha. They are commonly used to power vehicles, home heating and cooking appliances.

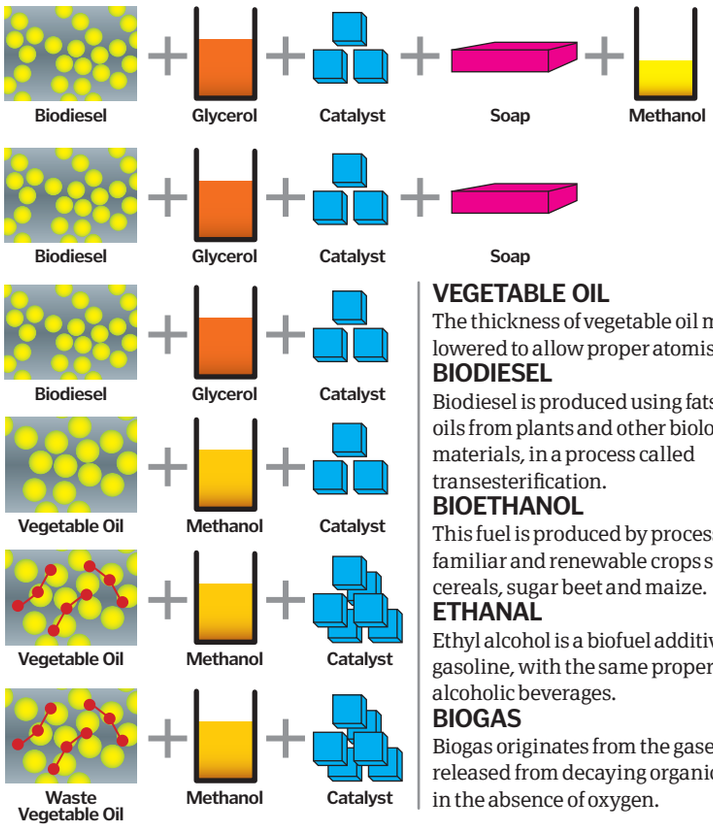
However, there are also some reservations related to biofuels. As well as environmental concerns they raise questions over detrimental effects to global provisions. For example, oil palm – a common agricultural produce – is grown at the expense of clearing biologically rich habitats, such as tropical rainforests. However, this is now giving way to more scientific exploration in biofuels produced from small developed spaces, rather than extensively on crop lands, such as the use of algae mentioned earlier. These can be grown using land and water that is unsuitable for plant or food production, preserving the food-fertile land. Plus they are still highly biodegradable and relatively harmless to the environment, as they consume carbon dioxide, which provides greenhouse gas mitigation benefits.

DID YOU KNOW?

Realistic projections share the belief that the production of biofuels will instigate an increase in the share of the world's fertile land to grow the necessary biomass. This increase will see the amount rise to four per cent by 2030. What this means is it will be possible to meet five per cent of road transport fuel demands, due to this first generation technology and cultivated area. There's also a realistic possibility that these second-generation biofuels could become commercially available.

DID YOU KNOW? *Biofuels are a renewable energy source, as we can simply grow as many plants as needed*

Types of biofuel



VEGETABLE OIL
The thickness of vegetable oil must be lowered to allow proper atomisation.

BIODIESEL
Biodiesel is produced using fats and oils from plants and other biological materials, in a process called transesterification.

BIOETHANOL
This fuel is produced by processing familiar and renewable crops such as cereals, sugar beet and maize.

ETHANAL
Ethyl alcohol is a biofuel additive for gasoline, with the same property as alcoholic beverages.

BIOGAS
Biogas originates from the gases released from decaying organic matter in the absence of oxygen.

How to make biodiesel

The creative process for producing biodiesel is an elaborate one. It begins with the filtering of waste vegetable oil, removing food particles. This can be achieved through extensive filtering processes. Once this is complete all water still contained within the residual gangue must be expelled. This is achieved by boiling the oil at 100 degrees Celsius, evaporating traces of H20.

Next the titration processes begin. This determines the concentration of mixable lye and methanol necessary. This process in turn requires an alkaline catalyst to increase the rate of the chemical reaction between the methanol and vegetable oil. Sodium hydroxide is the most commonly used, but potassium hydroxide is also acceptable. This instigates the production of sodium methodixe, creating a residue which is then heated up to as hot as 130 degrees Fahrenheit.

After this another good mixing is in order with the formula left to rapidly cool. Once the temperature has calmed the glycerine produced from this chemical reaction will sink to the bottom due to its density. Biofuels produced will float to the top. The catalyst, glycerol and vegetable oil can then all be easily separated at this stage.

However, the reheating process can cause the fatty acids bonded to the glycerol to break away. This is resolved by increasing the amount of catalyst in the single transesterification process, so that the additional catalyst neutralises the free fatty acids. This creates soap as an additional by-product.

Biodiesel in general should be compatible with diesel engines, however the main obstacle will be the parts attached, namely any rubber ones. This fuel's solvent powers are concerning, so any rubber piping and other parts in contact with fuel should be replaced with modern hard-wearing nylon pipes immediately to prevent any serious problems. Biodiesel is not a suitable fuel for spark ignition engines and considerable damage is likely to occur.

How petrol is made from crude oil

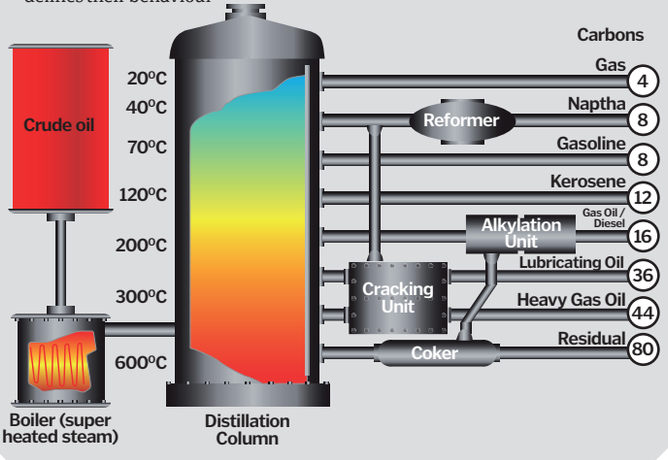
Discover how liquefied dinosaurs create fuel for your car

Petrol is refined from crude oil or petroleum. This is made up of the semi-fossilised, liquefied remains of prehistoric plants and animals which have, over millions of years, been crushed between layers of sediment in the Earth's crust. This causes the constituent elements (like us, dinosaurs were primarily made up of hydrogen and carbon at the atomic level) to break down into large, rich molecules known as hydrocarbons, which are packed full of organic goodness. They are basically made up of chains of hydrogen and carbon atoms strung together. The length of the chain controls the properties of the hydrocarbon. We extract crude oil from the depths of the Earth and use a chemical reaction called catalysis to control the length of the molecule chains and turn petroleum from dinosaur stew into petrol and diesel.

A catalyst is an element that when inserted into a chemical reaction makes that reaction happen faster and overall creates a much more effective end product. In the amusingly named cat-cracking process, crude oil is heated in a process called distillation. Different lengths of hydrocarbon chains have different boiling points, when they start to turn into vapour. The vapour is drawn off before being moved on to the next phase, where it's forced into a chamber with the catalyst. In this case, it's different grades of distilled petroleum, including the leftovers from the previous reaction. This makes the big hydrocarbon molecules crack into much smaller ones.

Larger, heavier molecule chains with more carbon break down into heavy oils and have a higher boiling point, while smaller molecule chains with less carbon rise into vapours again and become lighter substances such as naphtha. Standard petrol is manufactured to fall in the middle ground between the two. This is important, as being in this relatively balanced state it can withstand more compression without spontaneously exploding, making it reasonably stable.

The molecular length of hydrocarbons defines their behaviour



"The largest x-ray generator on Earth"

How to create 2 billion degrees Kelvin

Inside the Z ma

The machine that could offer the solution to the world's energy shortage

The electrifying Z machine is actually an x-ray generator, the largest on Earth. It is operated by Sandia National Laboratories from the company's main site in New Mexico. The machine is designed to test materials in conditions of extreme temperature and pressure.

The machine looks like something from a science-fiction movie with pulsing purple tubes. It sends a powerful electrical discharge into thin tungsten wires, which then vaporise and are transformed into a cylindrical plasma curtain. The machine uses a z-pinch process of fusion, a 'pinch' being what happens when you run current through plasma, and Z referring to the direction in cylindrical geometry.

Sandia runs a Z-Pinch Inertial Fusion Energy program (Z-IFE) in an attempt to harness fusion power. The Z machine can run at ultra-high temperatures, opening the theoretical possibilities of achieving fusion of light hydrogen atoms with lithium or boron, which would have no nuclear waste – clean fusion and the potential to create unlimited electrical power from seawater. Its achievements to date include melting diamond, shooting plates faster than the Earth moves through space and reaching the temperature of the Sun. Practically, it has allowed scientists to estimate conditions similar to the core of Jupiter and the surface of Neptune for astronomers to study. It could also enable the simulation of the effects of nuclear weaponry, meaning that they don't need to be physically tested.

Advances in the field back in the late Nineties meant that the machine was capable of outputting an x-ray power of 290 trillion watts, equivalent to 80 times the world's output of electricity. It began a retrofit program in 2004 to increase its power further, which was completed in October 2007 and reopened officially in February 2008. This increased the output from 18 million amperes to 26 million amperes (bearing in mind a 120-watt light bulb uses one ampere).

5 TOP FACTS THE Z MACHINE

Remodelling
1 The task of dismantling the machine in 2004 was undertaken to replace its 20-year-old equipment.

Save on power
2 Its work could stop our dependence on non-renewable fuels such as coal and gas extraction for energy.

In its roots
3 The machine was constructed as the Particle Beam Fusion Accelerator II back in 1985.

Book it out
4 The Z machine was overbooked before its remodelling with requests from labs and researchers.

Small target
5 The massive amount of power focuses entirely on a target the size of a spool of thread.

DID YOU KNOW? *The Z machine is housed at Sandia's main site in Albuquerque, New Mexico*

achine

The centre of this chamber can reach extraordinarily high temperatures

Image courtesy of Sandia National Labs

This month in **Space**

Our space experts have been extremely busy this month, bringing us some excellent, informative and fascinating facts on space, exploration and the solar system in the form of some fantastic articles. This Mars feature was so good it made it onto this issue's cover!

SPACE

Mission to Mars

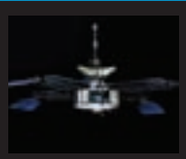
The past, present and future of exploration

The Statistics

Mars

Diameter: 6,780km
Mass: 6.4185 x 1,023kg
Surface temp: -125°C to 25°C
Escape velocity: 5.027km/s

28/11/1964 MARINER 4

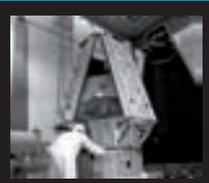


Country: US
Type: Orbiter
Outcome: Success
Details: First images of the Mars surface; disproved the existence of water beds but raised new questions about frozen ice.

19/5/1971 MARS 2

Country: Soviet Union
Type: Orbiter/ Lander
Outcome: Failure
Details: First human objects to visit the Red Planet, but communications were immediately lost after impact.

30/5/1971 MARINER 9



Country: US
Type: Orbiter
Outcome: Success
Details: Used two focal lenses for wide angle and standard lens; higher resolution transmissions using the 2.3GHz radio band.

20/8/1975 VIKING 1

Country: US
Type: Orbiter
Outcome: Su
Details: It took ten mo reach Mars, c first scientific about atmosp conditions ar stayed opera for six years.

5 TOP FACTS MARS

Mars rovers
1 One characteristic of the Mars rovers: they are exceptionally smart. As autonomous robots, they calculate how to get from one point to another, avoiding obstacles.

Spirit Rover
2 In May 2009, Spirit became stuck in deep Martian soil. Over the past six years, dust devils have cleaned the solar arrays of Opportunity, and is still on the move.

Mars spacecraft
3 A Mars spacecraft would likely weigh as much as the International Space Station (about 400 metric tons) and would be launched from low Earth orbit.

Phoenix Mars Lander
4 Named after the mythological bird that is reborn, the Phoenix was made up of 'spare parts' for a lower overall cost than the original Mars rovers.

MAVEN mission
5 The MAVEN (Mars Atmosphere and Volatile EvolutioN) mission in 2013 will collect atmospheric data to help engineers in a planned human mission.

DID YOU KNOW? *Mars's surface area is only slightly less than the total area of Earth's dry land*

Ayn Rand once said "the secrets of this earth are not for all men to see, but only for those who will seek them". She could have been talking about the planet Mars. Are there channels of water flowing beneath the surface? Polar ice caps that rise to kiss the Sun, stark and lonely? Sand dunes so deep they could consume nearby boulders? The planet has become a staple of science-fiction movies and rabid speculation. In the next 20 years, many of those mysteries could be unravelled, like layers of an onion.

Located about 1.1 astronomical units from our own planet (or about as far away from us as the Sun), Mars – known as the Red Planet – looks like a glowing red orb in the sky, just one reason the planet has become so interesting. Yet NASA and other space agencies around the world have made concrete plans to explore the planet, both by sending additional robotic landers and a planned human mission as soon as 2020.

"It is a scientifically interesting possibility that there could be life on Mars, either past or present," says Jeffrey Bennet, an astrophysicist and popular book author. "There is little question now that the planet has internal volcanic heat, polar ice caps, and a real possibility that there is liquid water below the surface of the planet."

Recent research captured by the Spirit and Opportunity Rovers still functioning on the planet after almost six years, along with a re-invigorated space program in the US, could make Mars exploration even more viable in the next 10-15 years.

The Opportunity and Spirit Rovers are the latest vehicles to visit Mars

Flybys and orbiters

First up-close images of Mars

Before the first orbital missions to Mars, astronomers often speculated that the planet showed what looked like river canals. In 1964, the first mission involved the Mariner 4 in a planetary flyby that revealed the truth: a rocky planet with a surface not unlike our own moon. According to Bennet, the first orbital missions showed portions of craters and sweeping sandy terrain but were important mostly because they showed it was possible to send a spacecraft to Mars. Bret Drake, the lead engineer for NASA, says the engineering required for the early orbital missions and to land on Mars involves complex scientific calculations. There were many communication challenges: while a lunar exploration involves real-time transmissions, there is a delay as short as six minutes and as long as 40 minutes between Mars and Earth.

Mariner 9, another flyby orbiting craft sent in 1971, showed more detail because it had two focal lenses, one for wide angle and one for normal focus. According to Bennet, Mariner 9 did not reveal any additional scientific clues, but showed the planet surface in more detail.

Brief history of Mars exploration

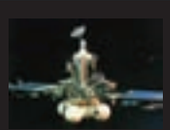
ORBITER

LANDER

9/9/1975 VIKING 2

Country: US
Type: Orbiter/Lander
Outcome: Success
Details: Lander and orbiter; took thousands of images until the batteries died.

7/7/1988 + 12/7/1988 PHOBOS 1/2

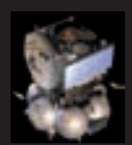


Country: Soviet Union
Type: Orbiter
Outcome: Success
Details: Successful in returning the first images of orbiting moons around Mars, but with a short life span due to software errors.

7/11/1996 MARS GLOBAL SURVEYOR

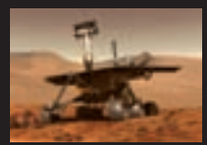
Country: US
Type: Orbiter
Outcome: Success
Details: First attempts to survey ice on Mars and determine if water occasionally appears.

2/6/2003 MARS EXPRESS



Country: Europe
Type: Orbiter
Outcome: Arguable
Details: Mineralogical mapping from orbit; included the Beagle 2 lander that didn't make it to the surface.

10/6/2003 MARS ROVERS



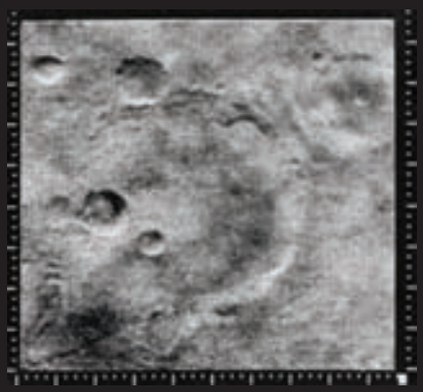
Country: US
Type: Landers
Outcome: Success
Details: Rovers intended to perform scientific experiments on Martian soil; still operational after six years.

4/8/2007 PHOENIX MARS LANDER

Country: US
Type: Lander
Outcome: Success
Details: Landed on the polar region to collect ice samples, searching for microbes to see if there is life on Mars.

All images courtesy of NASA (except Mars Express illustration by Medialab, ESA)

"The Mariner missions showed the first real hope that Mars was as exciting as we hoped"



Mariner 4's orbit

Seeing the big picture

In 1965, NASA's radio transmission technology was not unlike current communication techniques. Mariner 4 used the S-band frequency at 2.3GHz to send the images back to Earth. NASA later upgraded to the X-band and then the current Ka-band (at 32GHz).

According to James Garvin, the first Mars images from Mariner 4 were created using a primitive video camera that captured images using varying levels of electric pulses, at varying levels of light, and then converted the images to a digital signal.

"The Mariner missions showed the first real hope that Mars was as exciting as we hoped," says Garvin. "There were interesting landscapes; the planet was not just a flat lunar landscape and opened our eyes to doing the Viking lander missions."

Landers and rovers

Landing on the surface of Mars

In 1975, just four years after the last orbital mission with the Mariner 9 mission, NASA embarked on one of the most significant Mars explorations in history. The Viking missions involved two orbiters and two landers that would, for the first time, collect real scientific data from the Red Planet and transmit the results back to Earth.

According to James Garvin, the NASA chief scientist, the Viking missions were revolutionary in that they made several scientific discoveries: eg that the atmosphere is 1/100 of the Earth - much thinner. The Viking missions also mapped the surface of the planet, accurate within a couple hundred metres per captured pixel. The mission mapped the climate conditions, examined soil mixtures, and looked for trace gases, all using a mass spectrometer that captures data like a chemical fingerprint reader. Garvin says the Viking landers also created a geomorphology of the planet that showed the surface was sandy and dusty, yet does not change as much as the moon or large asteroids.

One of the most interesting findings involved examining the oxygen isotopes on the surface, and then comparing them to meteors found on Earth that astronomers believe came from Mars. The Viking missions eventually showed that Mars had a planetary make-up that is not unlike Earth: a volcanic core and a rocky surface, unpredictable wind conditions, long stretches of sunny days and static temperatures.

Yet the mission also showed that Mars does not have high levels of magnetic radiation on the surface, and the planet is likely to be extremely old. The mission showed that surface winds are not as harsh as once believed – they would not destroy a visiting craft.

"The Viking missions showed that Mars is a cold, sterile, dry desert of a world," says Garvin. "The missions gave us 25 years worth of data to examine."

Not your usual remote-controlled toys...

All images courtesy of NASA

Anatomy of a Mars rover

Solar-powered golf carts?

Launched in 2003, the Spirit and Opportunity Rovers are about the size of a golf cart. Each has a solar array that powers the vehicle, but the rovers only recharge during the day using a pack of lithium-ion batteries not unlike the one in a laptop computer. Because Mars is twice as far from the Sun as the Earth, solar charging is not nearly as fast as it is on our own planet, and the rovers only move about 100 metres per day at most.

Both have six wheels designed for the rocky tundra that propel the vehicle only a few centimetres per second. Because the rovers weigh about 172 kilos, they require a great amount of power to move – one charge provides only about an hour of movement, so they are – as Garvin describes them – like slow-moving turtles.

The three most famous crafts

Three famous Mars orbital explorers

Name: Mariner 4

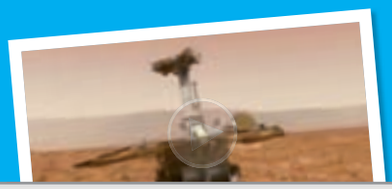
Famous for being first, Mariner 4 sent the first images of the surface of Mars back to Earth – disproving the river bed theories but revealing new possibilities, such as the likelihood of ice at the polar caps and in mid-latitude regions.

Name: Mariner 9

Mariner 9 was the orbiting craft that showed NASA that a Mars landing would be worthwhile, revealing greater detail about the lumpy surface, wind-blown dunes, and massive craters. Mariner 9 also revealed that what we thought were river canals were actually shadows from the sandy terrain and deep crevices.

Name: Mars Global Surveyor

The Mars Global Surveyor, launched in 1996, was the first time NASA sent an orbiting vessel to the planet in ten years. For the first time, NASA was able to capture images that showed traces of polar ice caps receding over time.

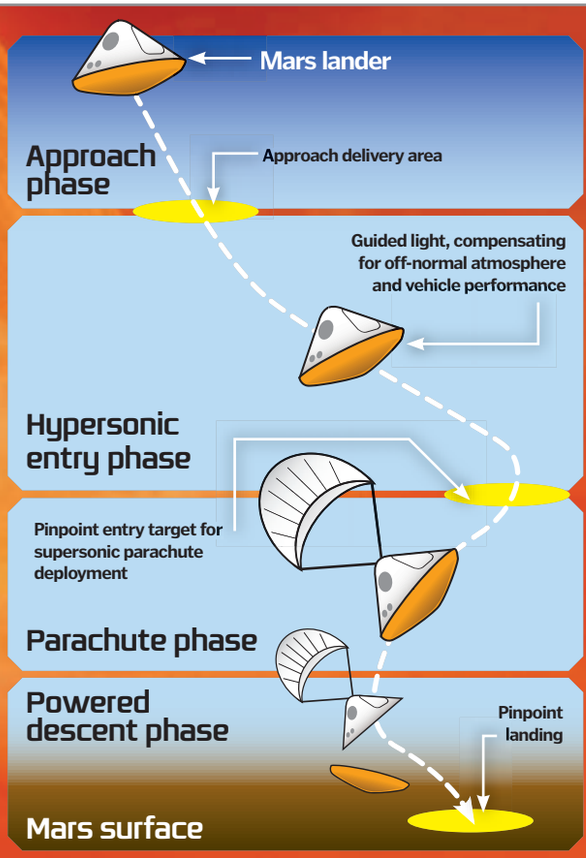


DID YOU KNOW? NASA hopes to send a manned spacecraft to Mars as soon as 2031

How a lander lands

Landing a vessel on Mars

Landing a vessel on Mars is part science, part luck, and part physics. According to Drake, the engineering involves precise calculations about relative orbits, but also takes wind conditions and temperature into account. The landing spot is usually about the size of a parking lot, says Bennet, and the calculations must determine the exact orbital alignment of the planet. Martian atmosphere is much thinner than Earth, so the landing requires even more precision to determine thrust and fuel consumption. Engineers determine well ahead of the landing where the vehicle will land based on the science to be collected. With the Phoenix Mars Lander, which landed in 2008, the goal was to collect ice samples, so the landing spot was the polar region on the tip of the planet.



How will man get to Mars?

Sending humans to Mars is a complex engineering task, but still possible

Sending an orbiter to Mars and landing on the desert planet is difficult; sending a manned mission is even more daunting. Over the past two years, NASA – under the direction of Bret Drake – has developed a detailed plan to send humans to Mars.

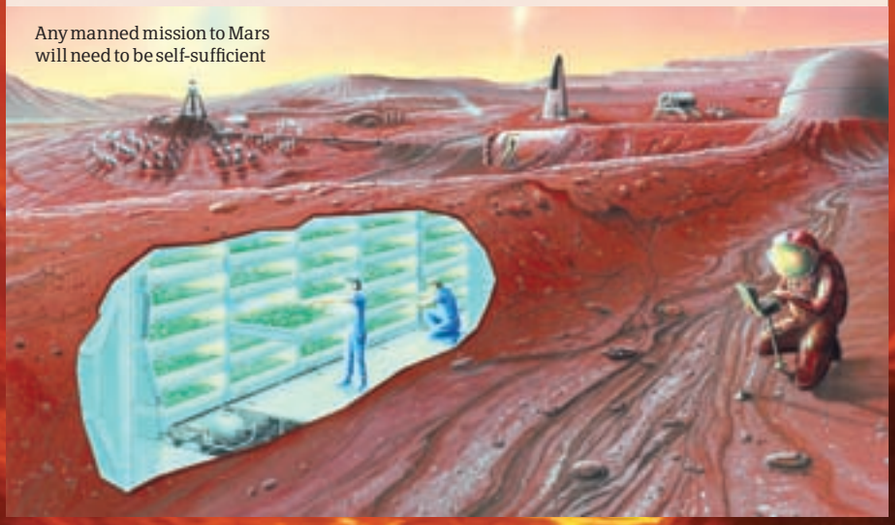
One of the most critical questions involves the number of people to send. Drake says it is a physics and economics debate. More humans would mean more discoveries but a greater overall cost and a slower trip. Fewer passengers mean a smaller vessel, lower costs, and a greater possibility for returning with samples.

His plan calls for sending supporting cargo vessels first. Since the orbits only align every 26 months, it means a fairly complex mission structure: sending the cargo vessels, getting the astronauts ready, waiting for the cargo to arrive as the human mission departs.

According to Drake, a mission to Mars would likely last about two years, including about a year collecting data on the planet. There is some debate, outside of NASA, that a first visit to Mars should be a one-way mission where the visitors plan to stay the rest of their lives, requiring far less fuel and more cargo such as food and water.

Drake says for a human mission to be successful, NASA engineers must devise a way for a Mars base to be self-sufficient: generating oxygen and power (likely using a small nuclear reactor) on its own.

Why a human mission? Drake says only humans can make random observations and perform complex tasks such as drilling below the surface.



Any manned mission to Mars will need to be self-sufficient

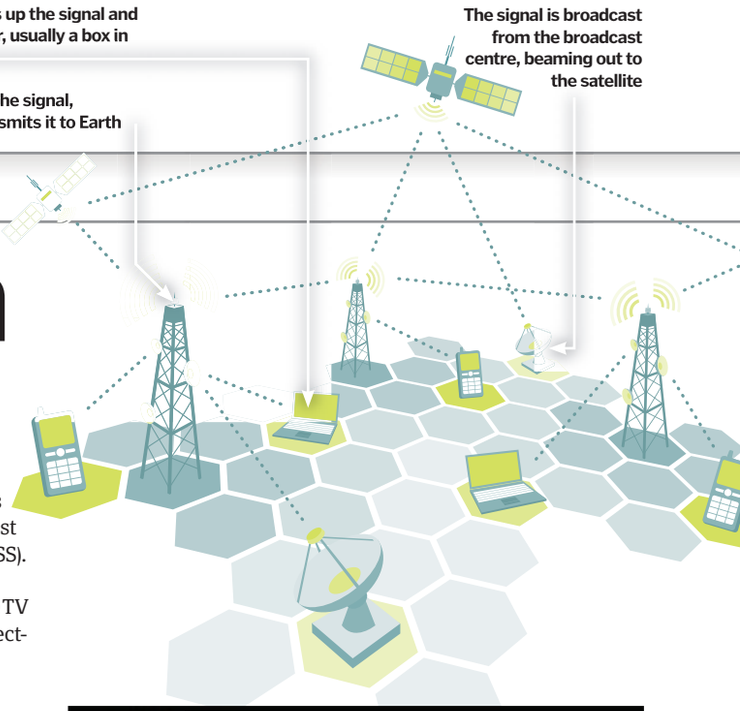
The Orion programme

How will Orion be used?

Interestingly, sending a manned vessel to Mars would require a massive power boost out of low Earth orbit and away from the moon. Once launched, there is no 'second attempt' so the mission must be successful. In order to make it all the way to Mars, the vessel would likely weigh as much as the Space Station (400 metric tons including the instrumentation and cargo), so it must be launched from Earth orbit because it is too heavy to launch from Earth. This is where the Orion spacecraft comes into play. The Orion, designed for a moon visit, would be used to get astronauts to the Mars vessel.

Communication satellites

How do they actually work?

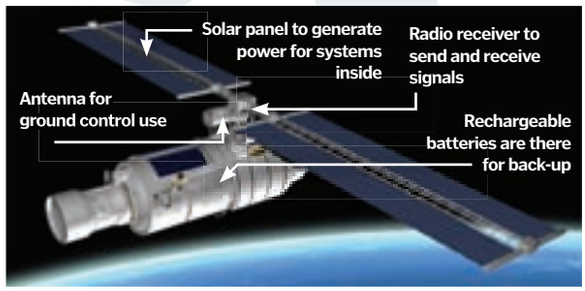


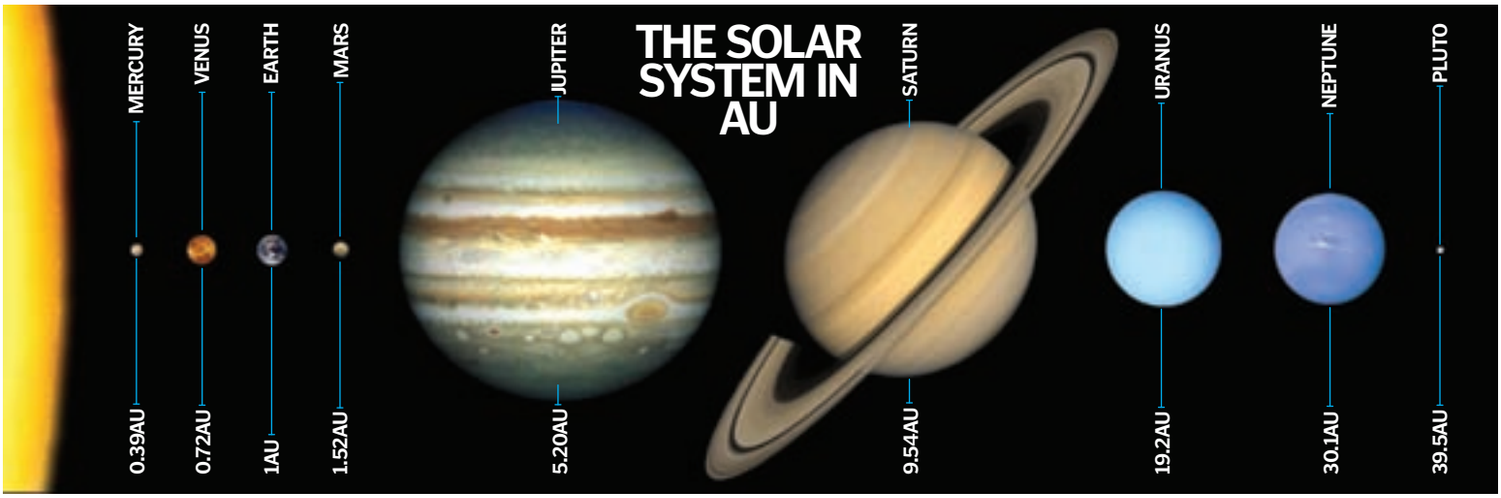
Satellite communications is simply communication via satellite, and these satellites (sometimes called SATCOMs) are what enable us to receive, for example, Sky TV, Freesat and DIRECTV (US) services, the latter of which is also available on some aeroplane journeys.

The satellites themselves are artificial and stationed in space with the key purpose of delivering telecommunications services. The first communications satellite to be launched was Project SCORE on 18 December 1958, which was used by American President Dwight Eisenhower to speak to the nation at Christmas as a display of telecommunications power. In the early days of satellite communications, they were used for telephony, allowing intercontinental long-distance calls, though satellite phones are much rarer nowadays.

The most popular use is in providing television and radio services, which utilises two different satellite types: Direct Broadcast Satellite (DBS) and Fixed Service Satellite (FSS). FSS is mostly used for broadcast feeds to television networks and free-to-air satellite TV channels, whereas DBS is what gives us direct-to-home satellite television via the services mentioned above.

Technically, communications satellites enable telephone and data conversations to be relayed using services like Telstar, and broadcast satellites are used for TV and radio transmissions, but they work in broadly the same way. A signal is sent to the satellite, which is converted via a transponder, amplified and sent back to Earth. Each satellite will typically have hundreds or thousands of these transponders. They can have a variety of different orbits, but most are geostationary.





Distance in space

How to measure the unfathomable expanses of space

When you consider the vastness of space, determining the huge distances between the planets in the solar system is clearly not a case of just whipping out your tape measure. We're talking massive distances here, so to make the calculations easier to comprehend, astronomers use a smaller unit to refer to such distances: the astronomical unit (AU). 1AU is equal to the average distance between the Earth and the Sun (about 150,000,000km). We take the average because the Earth's orbit is elliptical and so the distance varies. Astronomers have long known the nature of the orbits of the planets. The radius of Mars's orbit is just over one and a half times that of the Earth, making the average distance between Mars and the Sun 1.52AU.

The greater distances involved with measuring beyond the solar system render the astronomical unit redundant. The nearest star to our Sun, Proxima Centauri, is 4.3 light years away – that's some distance when you realise that one light year is 63,239AU and 1AU is 150,000,000km. In these circumstances, astronomers again rely on the geometry of the Earth's orbit around the Sun, only this time they use a method known as parallax to make their calculations. The easiest way to understand parallax is to close one eye and look at a star, then hold your thumb up over it. Next, keeping your thumb still, close your other eye instead and you'll notice the star appears to have moved. On a much larger scale, imagine your two eyes as separate points on the Earth's surface looking at the star. Knowing the Earth's orbit around the Sun, we can view the same star from different positions and, by triangulating the angles of light from the star from two points into one, calculate the distance to the star.

For further galaxies and stars the angles involved are too small to distinguish in this way and require a different method of measurement.

5 TOP FACTS STARS

Black dwarf
1 It takes 10 trillion years for a white dwarf to cool off entirely. Our galaxy isn't even old enough for a black dwarf to physically exist yet, but it lies in our Sun's future.

Closing the curtains
2 The universe hides the birth of stars from us behind a curtain of dust. Only here are conditions cool enough for the dust and gas to condense and fire-up into new stars.

We're made of stardust
3 Every single element that is in the periodic table was created via fusion processes deep inside the cores of stars, or indeed recycled by supernovae.

Nova is new
4 While the death of a star via supernovae is violent, it's all part of the circle of life. New star-forming regions form as a result and sow new seeds across our galaxy.

Very heavy metal
5 Between nine and 12 miles across, neutron stars are so incredibly dense that just a teaspoonful of its material weighs as much as a billion tons.

DID YOU KNOW? *The last supernovae to be seen in the Milky Way was Kepler's Supernova which was first observed in 1604*

The collapse of a massive star can lead to a black hole

Image courtesy of NASA

What happens when a star dies?

Exploding in the universe's biggest fireworks display and shrinking so infinitesimally small that physics breaks, stars really know how to go out with a bang...

The candle that burns twice as bright burns half as long. The saying might be considerably older, but you can thank a quote from the sci-fi classic *Blade Runner* for inadvertent encapsulating the life and death of a star. It was either that or a line from *Candle In The Wind* by Elton John, so just be grateful.

Stick it on a chart with every other kind of star and our Sun would sit right in the middle and sadly, this doesn't make for the most exciting swan song in 5 billion years time. Once all the hydrogen fuel is depleted our Sun will start to burn helium and its change in diet will gradually blow it up in size until its edges reach as far out as our current orbit (yes, a heat death awaits the Earth in half a dozen billion years). This cooling red giant will eventually collapse, expelling its outer shell in a relatively docile act leaving a planetary nebula in its wake with our Sun's tiny glowing remnant in the centre.

In the grand scheme of things the death of a small star like our Sun is pedestrian – what happens when a massive star dies is much more impressive and can even conclude with the creation of the most awe-inspiring and destructive force in all of nature; a black hole.

Once the supply of fuel for nuclear fusion runs out, massive stars grow in much the same way as smaller stars like our Sun, but much bigger and are classified as 'super massive'. Instead of blowing off its outer shell with a gentle 'puff' like a red giant, a cataclysmic explosion occurs, shedding material into an almost perfect bubble formation expanding at a tenth the speed of light and expending roughly the same amount of energy in a single manoeuvre as our Sun does in its entire 10 billion year life span.

Astronomy novices and experts alike will benefit from a visit here

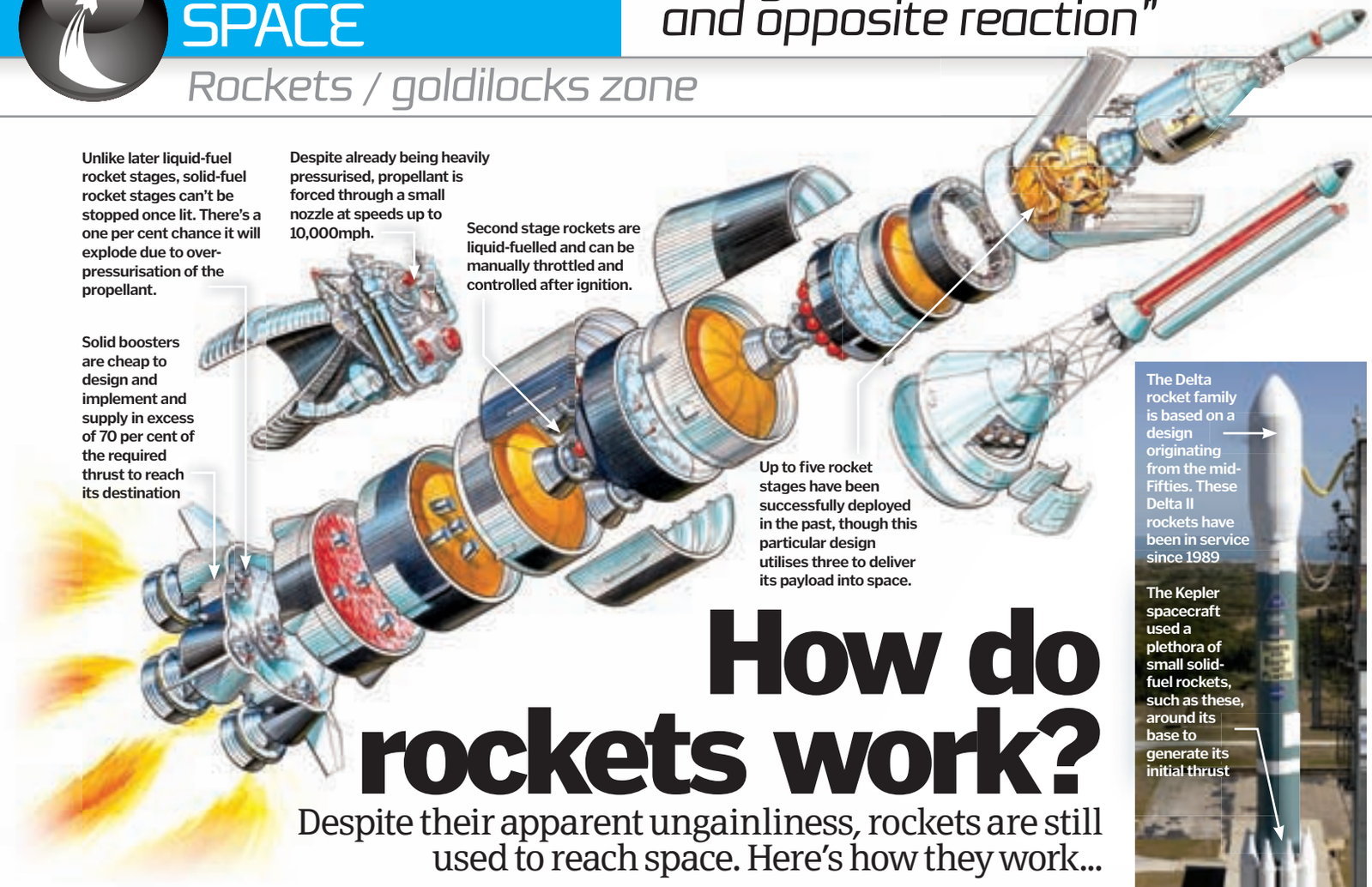
How to see the stars for yourself

You won't see a supernova but this astronomy centre offers some great trips

With nearly 40 years' experience, the stargazers at Scotland's Galloway retreat are devoted to sharing the beauty and fascination of the sky at night with visitors from all over. Whether you're an eager beginner or a seasoned astronomer, you'll appreciate Galloway's dark skies and practically nonexistent light pollution.

The centre's knowledgeable staff are on hand to give talks and guide you through the vast night sky, and a variety of educational courses are also available. So why not book a short break at the Galloway Astronomy Centre during the next meteor shower? To find out more, head over to www.gallowayastro.com.

"Every action has an equal and opposite reaction"



How do rockets work?

Despite their apparent ungainliness, rockets are still used to reach space. Here's how they work...

Every action has an equal and opposite reaction. Though it's highly unlikely Newton actually had space rockets in mind when he wrote his famous Third Law, it rather accurately and elegantly explains exactly how they work.

Of course to shift a giant rocket, replete with weighty payload, beyond the Earth's gravitational pull requires quite a reaction – remarkably, an object must be moving at nearly seven miles per second to clear Earth's surface gravity.

To facilitate the sheer mass of fuel required to move a small payload into space, multi-staged rockets are used. By discarding these so-called 'stages' once spent, the mass of the remaining rocket is less, therefore further thrust (and fuel) requirements are eased.

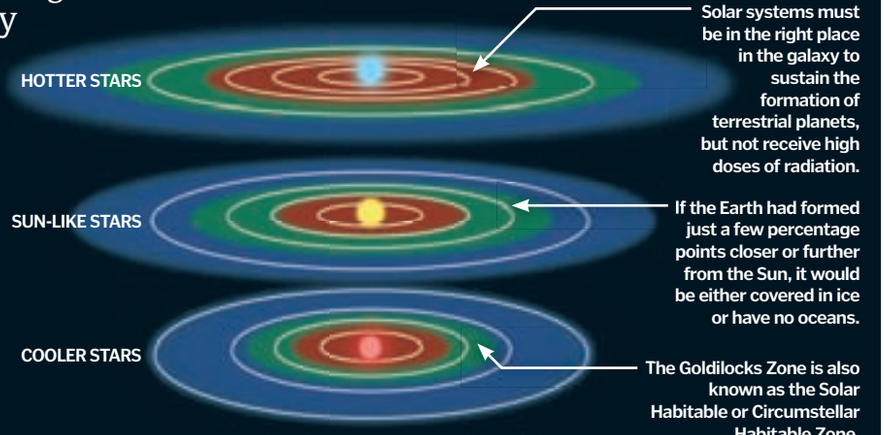
First stage rockets are solid-fuel boosters, which force highly pressurised propellant through a nozzle at up to 10,000mph to generate their thrust. Second stage rockets are liquid-fuelled boosters which can be controlled to their destination, but generate less thrust.

The Goldilocks Zone explained

Life-sustaining planets require such exacting standards that scientists call the area they occupy 'the Goldilocks Zone'

The Goldilocks Zone is an area 'just right' for a life-sustaining planet – the perfect distance from a star with a surface neither too hot nor too cold. It is an intersection of life-sustaining regions within both a solar system and a galaxy. Astronomers believe that the Goldilocks Zone ranges from 0.725 to three astronomical units (each about 150 million kilometres, or the mean distance between the Earth and the Sun).

Recently some planetary bodies have come close to fitting the bill. The April 2007 discovery of Gliese 581c in the Libra constellation, for example, seemed promising until further research proved it was too hot. However, a nearby planet, Gliese 581d, may turn out to be just right. At the same time, the definition of the Goldilocks Zone is expanding as scientists discover life on Earth in places previously thought too extreme to sustain it.



Life-sustaining planets require specific conditions

What makes Jupiter?

Massive planet acts as a comet catcher

Ten times bigger than Earth, Jupiter is a massive planet – the largest in our solar system, and perhaps the most beguiling. According to Dr Chris De Pree, a professor of physics and astronomy and director of the Bradley Observatory at Agnes Scott College in Decatur, Georgia, the planet has an interesting role in life: it has acted like a magnet, pulling stray comets into its gravitational field.

Made up of 90 per cent hydrogen and ten per cent helium, Jupiter is a gaseous ball not unlike the Sun. Yet the planet is incapable of producing the same atomic reaction that warms your skin on a sunny day because the planet still does not have the gravitational pull, intense heat, and mass required to make atoms collide. Interestingly, while astronmers search for signs of water and ice on Mars, we know Jupiter has both.

"Jupiter and the outer planets are mostly made of atmosphere," says De Pree, explaining that the planet formed by accreting the nearby space dust, ice and other materials in the solar system, but even the core is not a rocky surface like the outer layers of Mars or Venus. That means if we ever did visit Jupiter, we'd find thick layers of gas.

Another unusual feature is that there's a Great Red Spot on Jupiter that scientists believe is a hurricane that has nowhere to land and has persisted for hundreds of years (on Earth, hurricanes make land-fall, but there is no land on Jupiter). The hurricane looks red because of the sulphur and phosphorous compounds, explains De Pree.

The Statistics

Jupiter

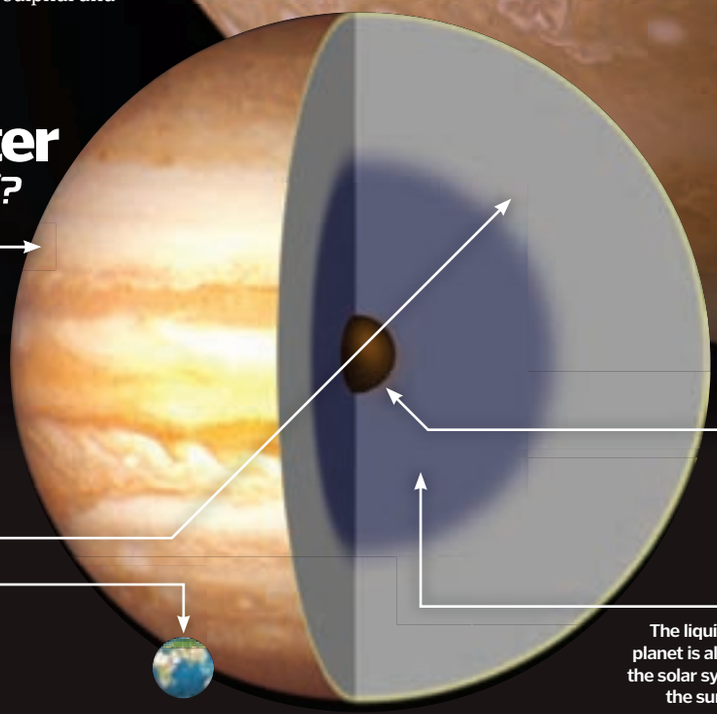
Diameter: Ten times Earth
Mass: 300 times Earth
Density: Second highest of gas planets
Average surface temp: Thousands of degrees
Core temp: Tens of thousands of degrees

Jupiter's moons

Jupiter has dozens of orbiting moons – astronomers are not sure on the exact number, but there are at least 63 that have been sighted. Galileo first discovered the moons over 400 years ago – they are only visible through a telescope, but you don't need one that is high-powered. Jupiter has a massive magnetic field that extends all the way to Saturn, which is why there are so many orbiting moons. In fact, the planet has acted like a magnet for comets and asteroids. A comet swept by Jupiter in 1994 and orbited once before it eventually crashed into the atmosphere.

Beneath the surface of Jupiter

What is Jupiter made of?



Surface atmosphere
Jupiter has a thick, gaseous outer atmosphere made up of liquid hydrogen. When the planet formed, it pulled (or accreted) nearby hydrogen and other gases and left them in the outer regions as the planet started its orbit around the Sun.

Liquid hydrogen
Hydrogen was pushed to the outer areas of Jupiter as the heavier materials – including iron and silicon – formed in the centre of the planet.

Ten times bigger
If Jupiter were a swimming pool, you could line ten of our planets from one end to the other, but you could fill the pool with 1,000 of our Earths.

Iron-silicate core
The core of Jupiter is made up of iron and silicon, and churns at a temperature of tens of thousands of degrees – still much cooler than the Sun and not capable of producing the nuclear fusion required to turn the planet into a star.

Liquid metallic hydrogen
The liquid metallic hydrogen below the surface of the planet is also formed by accreting these materials from the solar system, but heavier materials formed closer to the surface due to the gravitational pull of the core.

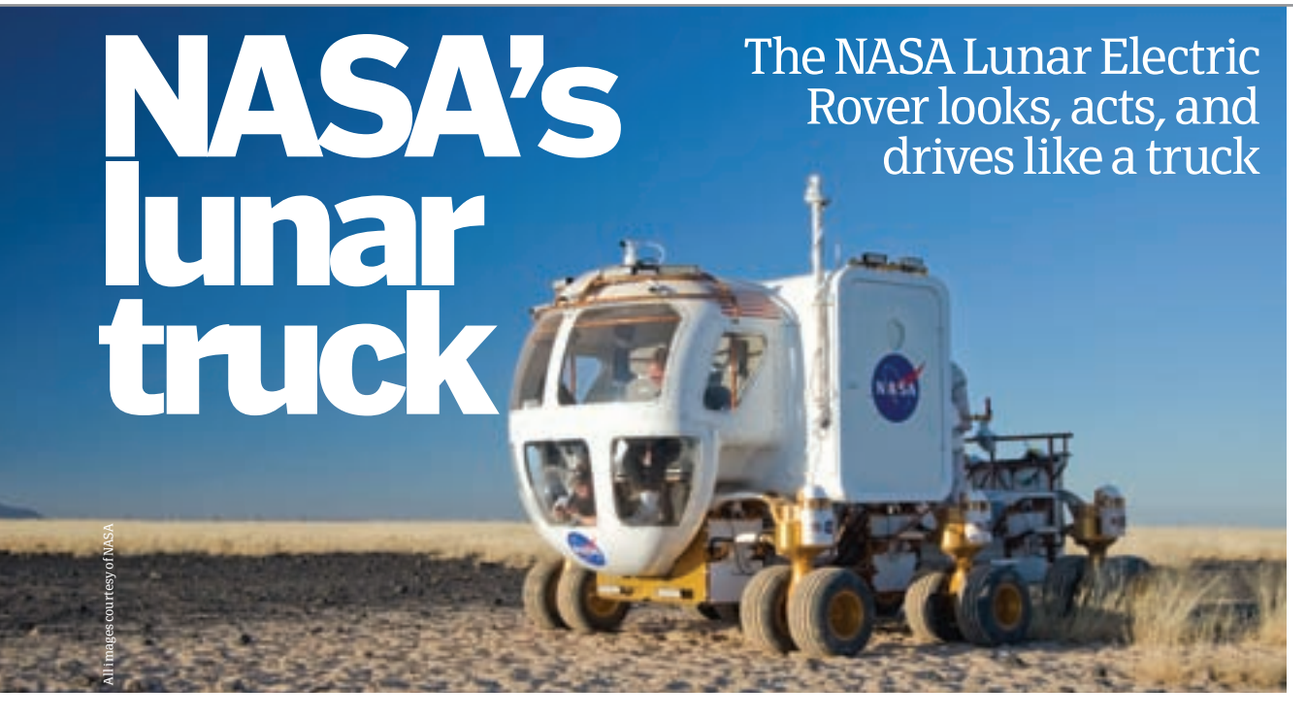
All images courtesy of NASA

"An all-terrain behemoth that will join astronauts on a mission to the moon in 2020"

Keep on truckin' on the moon

NASA's lunar truck

The NASA Lunar Electric Rover looks, acts, and drives like a truck



All images courtesy of NASA

It may only be Arizona, but these test runs will help the effectiveness of the Lunar Electric Rover when it's finally used

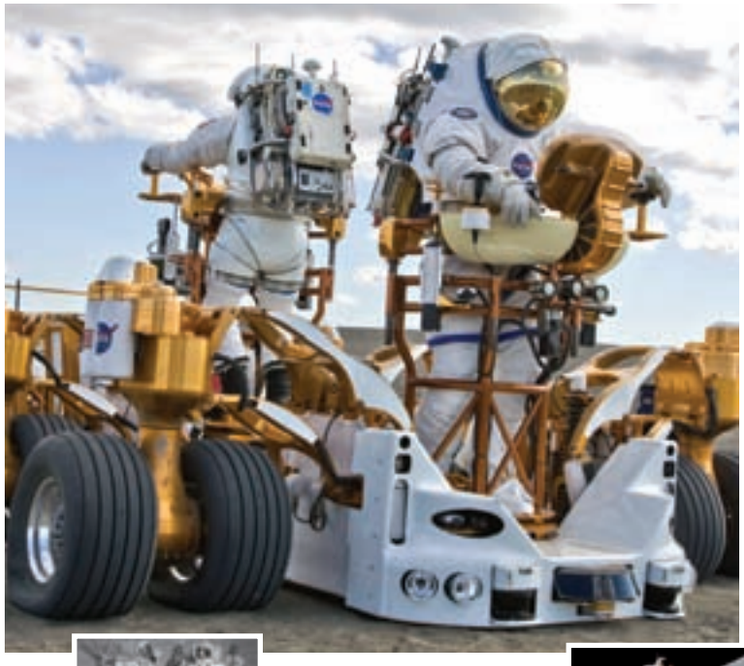
The size of a pick-up truck, with 12 wheels that measure about 12cm in diameter each, with a front chassis that rotates in all directions, the Lunar Electric Rover is an all-terrain behemoth that will join astronauts on a mission to the moon in 2020.

In September, NASA tested the first prototype lunar truck at the Black Point Lava Flow in Arizona. The vehicle, which weighs 3,000kg and stands three metres high, is capable of rambling over boulders with ease, and also features a wide viewing glass in front of and just below astronauts. According to Barrett S Caldwell, an associate professor of industrial engineering at Purdue University briefed in the project, the lunar truck is a bold step for NASA to help astronauts conduct long-term scientific experiments on the moon, drive for hundreds of kilometres, and explore any anomalies.

"The lunar tuck allows astronauts to live in a warm, safe, and healthy environment, drive to a spot on the surface, get into their suits, and conduct experiments," says Caldwell.

The lunar truck will be powered by solar panels, and energy will likely be stored on fuel cell batteries that have not even been invented yet. Astronauts will have to plan excursions using the power obtained from sunlight for 14 days at a time (the moon has 14 days of sunlight followed by 14 days of darkness). Caldwell says the roving vehicle will act like a remote space station and provide beds, kitchen, and 'sanitary' facilities for astronauts, who can wear shirt-sleeves and socks to conduct lunar missions.

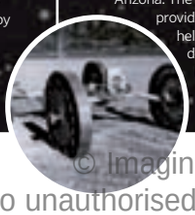
One of the main hazards for driving on the moon has to do with lunar soil blocking the views from the vehicle and seeping into the engine. Astronauts will carefully plan missions and the vehicle will be sealed from abrasive sand. The 'extreme off-road' truck will use steel-enforced tires that do not require air inflation, says Caldwell. Astronauts will drive the truck only a few kilometres per hour, although it is capable of going about ten per hour or more. During missions, astronauts will have to be leery of large rocks and massive drop-off ravines, which are hard to see, that could cause the truck to lift several metres into the air – since the 3,000kg vehicle will weigh only 500kg on the moon – which has 1/6 the gravity of Earth. Other hazards include solar radiation, especially for remote experiments, which was also a concern for previous lunar landings.



LUNAR VEHICLE HISTORY

1964 The data that was provided by the Mobility Test Article (MTA) helped in designing the Lunar Roving Vehicle (LRV). The LRV was designed to allow Apollo astronauts a far greater range of mobility during their lunar exploration missions.

1965 This MTA was a concept of a possible dual mode LRV built by the Grumman Industries for NASA's Marshall Space Flight Center (MSFC).



1969 This Mobility Test Article, built by the Bendix Corporation for NASA's Marshall Space Flight Center, was driven over a range of rocks in Arizona. The data that was provided by the MTA helped in designing the Lunar Roving Vehicle.

1970 This LRV was a lightweight electric car designed to increase mobility and productivity of astronauts on the lunar surface. It was used on the last three Apollo missions; 15, 16 and 17.

1971 Astronaut James B Irwin, lunar module pilot, works at the Lunar Roving Vehicle during the very first Apollo 15 lunar surface extravehicular activity at the Hadley-Apennine landing site.

1972 Astronaut Eugene A Cernan, commander, makes a short checkout of the Lunar Roving Vehicle (LRV) during the early part of the first Apollo 17 Extravehicular Activity (EVA-1) at the Taurus-Littrow landing site.

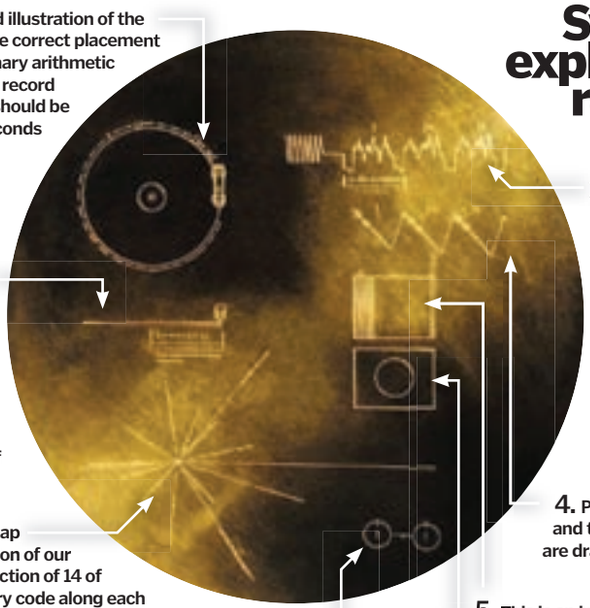
DID YOU KNOW? *The Voyager messages were the brainchild of US astronomer Carl Sagan*

Interpreting Voyager's message

The Voyager spacecraft contains gold records designed to explain life on Earth to extraterrestrials that may encounter it

When NASA sent out its Voyager spacecraft, it included a record on each probe as an example of life on Earth. Made of gold-plated copper, the record was designed in 1977 by a committee chaired by Carl Sagan. In addition to 115 images and a variety of nature sounds, the record includes greetings in 55 languages and dialects as well as selections of music. The record's cover is electroplated uranium-238, which can be used to date its age. In the upper-left corner are drawings of a record, with binary arithmetic to indicate how it is played. The bottom-left image is a map, showing the frequency and location of the Sun's pulsars. The waves of picture signals are illustrated in the upper-right corner, with a final image replicating the first image on the record. The bottom-right image is of the lowest states of the hydrogen atom, indicating the time interval.

Symbols explain the record's use



1. This overhead illustration of the record shows the correct placement of the stylus. Binary arithmetic surrounding the record explains that it should be played at 3.6 seconds per rotation.

2. A side-view of record and stylus has binary arithmetic below it to show that the record has about an hour of play time.

3. This diagram and the three below explain the images on the record. The wavelengths illustrate how pictures are constructed of analogue video signals, with binary arithmetic showing that each scan lasts eight milliseconds.

4. Picture lines one, two and three show that they are drawn vertically with a staggered interlace.

5. This is an image frame showing that each scan is vertical and each image contains 512 lines.

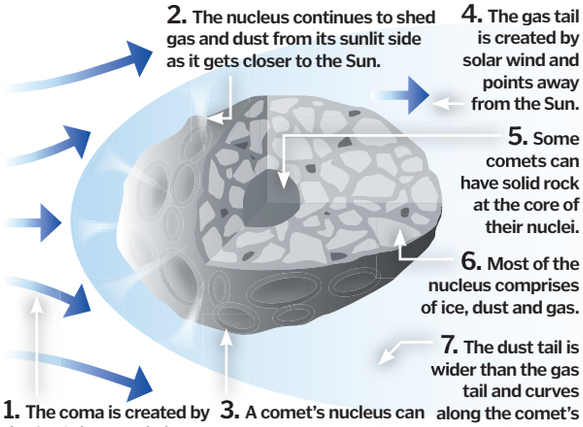
6. If the pictures are rendered correctly, the first image on the record should match this image.

7. This pulsar map shows the location of our Sun and the direction of 14 of its pulsars. Binary code along each pulsar gives the frequency.

8. This illustration shows the two lowest states of the hydrogen atom. The vertical lines and dots show the spin moments of each atom's proton and electron. The connecting line and '1' show that the transition from one state to another is to be used as the timescale for all pictures on the cover as well as on the record.

Anatomy of a comet

Comets can contain everything from dust and ice to methane and rocks



1. The coma is created by the Sun's heat and glows due to light reflection.

2. The nucleus continues to shed gas and dust from its sunlit side as it gets closer to the Sun.

3. A comet's nucleus can range from one to 100 kilometres in diameter.

4. The gas tail is created by solar wind and points away from the Sun.

5. Some comets can have solid rock at the core of their nuclei.

6. Most of the nucleus comprises of ice, dust and gas.

7. The dust tail is wider than the gas tail and curves along the comet's path like water from a hose.

Comets are made of debris from the formation of the outer planets. While all comets orbit the Sun, short-period comets (fewer than 200 years) orbit in a region of the solar system beyond Neptune's orbit called the Kuiper belt. Long-period comets (more than 200 years) are thought to orbit in the Oort cloud, a spherical cloud of comets nearly one light year away from the Sun.

Dust and ice provide the bulk of most comets, although they often contain gases like methane as well as rocks or carbon. A comet's nucleus can range from one to 100 kilometres in diameter. Surrounding it is a cloudy atmosphere made of evaporated gas and dust called a coma, which can be up to a thousand times larger than the nucleus. Comets also have one or two tails. The dust tail is made of particles that have been pushed away from the nucleus by the Sun's radiation. It faces away from the Sun and can be several million kilometres long. The second tail is the ion or gas tail, comprising of gas molecules that are electrically charged and have been pushed from the nucleus by solar wind. The ion tail comes straight behind the nucleus, and can disappear and reappear depending on the comet's orientation in the Sun's magnetic field. It can be even longer than the dust tail.

WASP-12b is a super-hot, super-fast planet

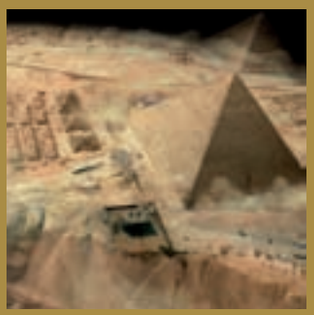
Image courtesy of NASA

Is this the hottest planet in space?

WASP-12b is one of the fastest orbiting, hottest planets we've found

Of all the strange anomalies we have discovered in the known universe, one of the strangest is the planet WASP-12b. Orbiting just .002 astronomical units from its sun (one astronomical unit is the distance between our Sun and the Earth), the aptly named WASP-12b (and the very recently discovered WASP-18b) is so large, moving so fast, and is so hot – at about 2,250°C – that it should probably be a star, says Patricia Reiff, the director of the Rice Space Institute in Houston. Most 'hot Jupiter' planets that mimic the gaseous giant in our solar system are much farther out in the solar system. WASP-12b is located about 800 light years from Earth, so we can only get a faint picture of why it has not turned into a small rock by now.

Interestingly, most planets this hot and this fast do become stars even while in orbit or just boil off into nothing.



This month in **History**

We kick off the History section this month with a look at one of the Seven Wonders of the Ancient World: the awe-inspiring Great Pyramids at Giza. The mystery of how this and other pyramids were constructed has been baffling experts for centuries, but has a new theory finally revealed the truth? Not only that, but we also have an insight into the world's first computer and its inventor Charles Babbage, not to mention a look at the Nazi-made V-2 rocket...

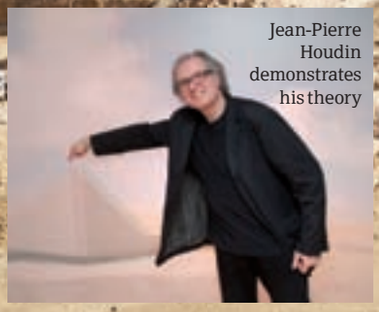
78 Discover the V-2 rocket

78 The first plane

81 The first computer

HISTORY

Mystery of the Great Pyramid



Jean-Pierre Houdin demonstrates his theory

The theories of French architect Jean-Pierre Houdin may hold the key to an ancient mystery

Although Egyptologists have been studying the Great Pyramid of Khufu for centuries, they haven't yet reached a consensus on how it was built. Specifically, how were the massive two-ton blocks placed 480 feet above the desert floor? A French architect named Jean-Pierre Houdin has formed a theory to explain the mystery. Houdin has devoted his time to studying the Great Pyramid and creating graphical models using 3D software.

Houdin believes that an external ramp was built to haul the rocks – pulled by means of ropes – for the first 60 metres or so of the pyramid. Then an internal ramp was built to continue hauling rocks up. It is a mile-long narrow structure spiralling inside the pyramid much like the ramps in a parking garage. To allow for men to haul the stones, the ramp is at a seven per cent slope. Somehow it has remained hidden inside the pyramid since its completion 4,500 years ago.

However, how would men hauling the blocks up the ramp be able to make the turn at each corner of the ramp? They would need a place to stand in front of the blocks. Houdin believes that each corner was temporarily left open, with a notch of about three square metres. Wooden cranes were stationed in each of these open spaces to lift the blocks onto the next level of the ramp. Later the notches were filled in.

There is some evidence that an internal ramp exists. In 1986, a team of

THE STATS GREAT PYRAMID

YEAR BUILT **circa 2550 BC** TOTAL MASS 5.9 million tons

NUMBER OF STONE BLOCKS 2.3 million (approx) HEIGHT **481 feet**

Building a pyramid from the inside out

The Great Pyramid has both ascending and descending chambers

The King's chamber
This is the main chamber of the pyramid. Unlike later pyramid chambers, its walls are blank. A granite sarcophagus sits inside, but no lid has ever been found.

The Queen's chamber
The name of this chamber is a misnomer. Many Egyptologists believe that it was originally built for Khufu. However, as he was still living when the chamber was finished, it was abandoned.

Unfinished subterranean chamber
This chamber lies below ground level. It may have been built in case Khufu died early, but he may have also simply changed his mind about where he wanted to be buried.

Relieving chambers
Houdin believes that these chambers were built to relieve weight on the King's Chamber. Others have thought that they were for ventilation or to allow Khufu's soul to rise to heaven.

The grand gallery
This long, narrow room slants upwards. It has a corbelled ceiling and benches along its sides, with slots cut into each bench. Egyptologists aren't quite sure about its use.

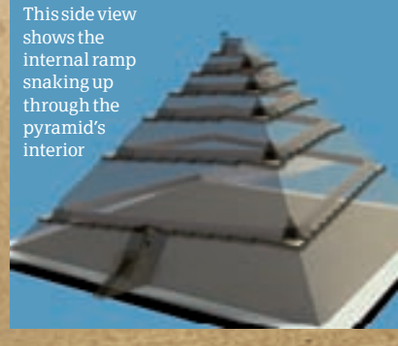
The entrance
The entrance wasn't created until 820 CE by Caliph Al-Ma'mum, who tunnelled into the pyramid so they could search for treasure. The original entrance was sealed after the pyramid's completion.

According to Houdin, openings were left at the corners so workers could use the internal ramp

French scientists used microgravimetrics to survey the pyramid. They were looking for hidden chambers by checking for areas of low density, which would indicate open spaces. The team did find one new chamber that was filled with sand. However, one diagram puzzled them – there appeared to be a low density spiral inside the pyramid. In 2000, a member of the team met with Houdin and showed him this scan, which lends weight to his internal ramp theory.

During a 2007 visit to the Great Pyramid, Egyptologist Bob Brier pointed out two more features that could be evidence of the ramp. When the Sun hits the pyramid at a certain angle, you can see broad white lines at a seven per cent angle running around it. Brier climbed the pyramid to examine what appeared to be a notch. Although it had irregular measurements, there was a small chamber that he had never heard about before. It could be the remains of the open notch leading to a ramp. In addition, Brier has pointed out that the Sun Temple, built 100 years after the Great Pyramid and now partially in ruins, contains an internal ramp. This shows that the Egyptians were building these types of ramps.

Working with the former director of the German Archaeological Institute, Houdin's petitioned the Egyptian Supreme Council of Antiquities to survey the pyramid in a non-destructive way. If he gets the go-ahead, he may be able to prove his theory after all.



This side view shows the internal ramp snaking up through the pyramid's interior

The old theories debunked

Houdin's theory is very different from the traditional theories

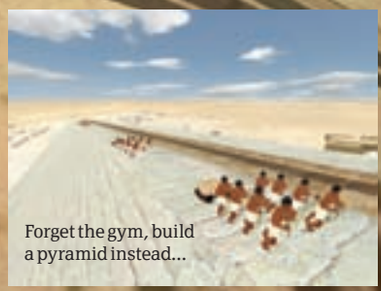
Plateau
The pyramid is built on a plateau. Its north side has a very steep drop-off, making it unsuitable for the placement of an external ramp.

External ramp
Many Egyptologists believe that an external ramp was used to build the pyramid. This ramp would've been massive and required nearly as many stones as the pyramid itself to build.

Cemeteries
The pyramid has cemeteries to its east and west, which were built at the same time. This means that an external ramp could not have been placed there.

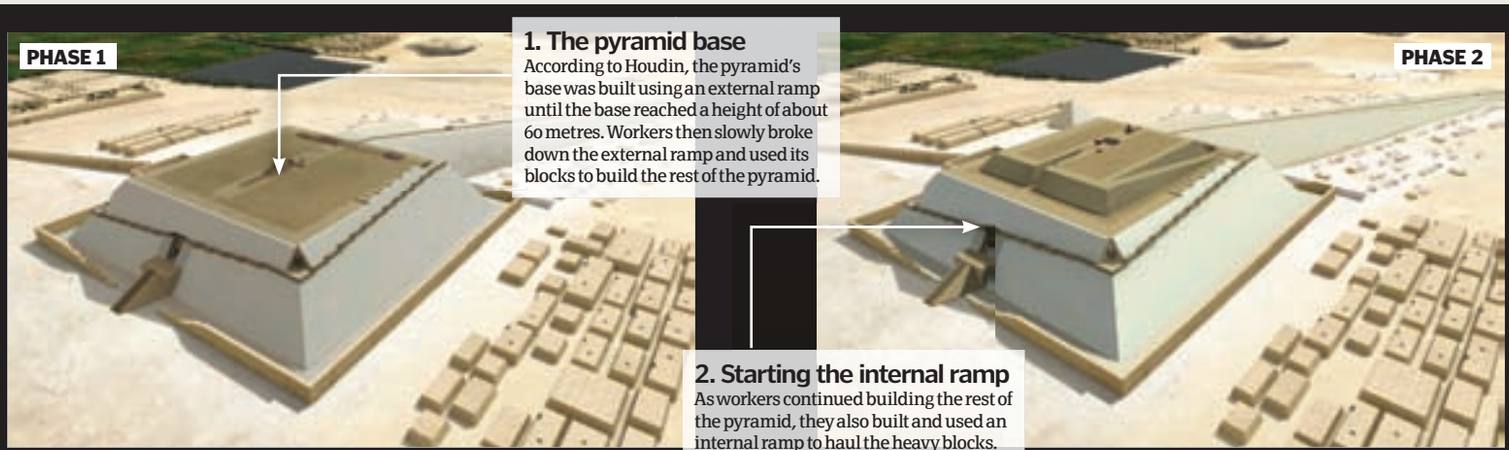
One common theory states that an external ramp was used to haul the blocks all the way to the top. The problem is that there isn't anywhere around the pyramid to place a ramp of this size. The pyramid is built on a plateau, with a steep drop to the north. Cemeteries were built at the same time as the pyramid to its east and west. In order to maintain the correct seven per cent slope all the way to the top, a ramp built to the south would've been a mile away from the pyramid. This huge undertaking of labour and use of materials seems impractical.

Another theory maintains that there was a spiral ramp coiling around the outside of the pyramid. However, this type of ramp wouldn't allow the pyramid's architect, Hemiunu, to maintain the sight lines necessary to ensure that the pyramid's faces met correctly at its top.


Forget the gym, build a pyramid instead...

Building a pyramid STEP-BY-STEP

Houdin's theory posits that the pyramid was built with two ramps



1. The pyramid base
According to Houdin, the pyramid's base was built using an external ramp until the base reached a height of about 60 metres. Workers then slowly broke down the external ramp and used its blocks to build the rest of the pyramid.

2. Starting the internal ramp
As workers continued building the rest of the pyramid, they also built and used an internal ramp to haul the heavy blocks. This allowed them to build the pyramid from the inside out.

DID YOU KNOW?

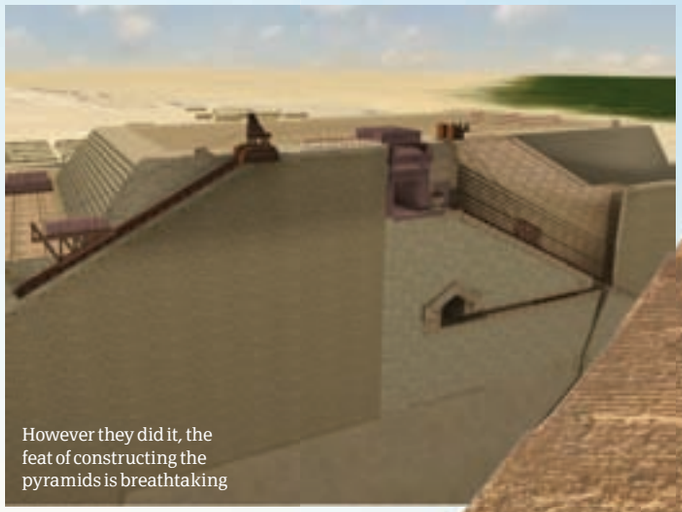
Massive workforce...

It is estimated that during the 80 years it took to build the pyramids at Giza, between 20,000 and 30,000 workers had a helping hand in their construction.

A search for truth

Dr David Jeffreys, an Egyptologist at University College London, has suggested that Houdin's theory is "far-fetched and horribly complicated." Houdin has countered this by saying that his theory is actually no more complicated than the idea of building a one-mile-long ramp leading up to the top of the pyramid.

Dr Zahi Hawass, Secretary General of the Egyptian Supreme Council of Antiquities (SCA), seemed to initially consider Houdin's theory as a possibility. However, in a 2009 interview, Dr Hawass stated that Houdin's theory is "completely wrong" and "the theory of other theorists". Houdin has invited Dr Hawass to lead the survey of the pyramid.



However they did it, the feat of constructing the pyramids is breathtaking

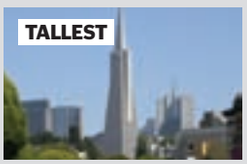
Head to Head PYRAMIDS

1. Great Pyramid of Cholula

Location: Cholula, Puebla, Mexico
Height: 66 metres (217 feet)
Estimated age: 1,000 years
Facts: This pyramid was built in four stages and has a volume of about 4.45 million square metres.

2. Pyramid of Djoser

Location: Northwest of Memphis, Egypt
Height: 62 metres (203 feet)
Estimated age: 4,600 years
Facts: Built for the Pharaoh Djoser, this pyramid comprises six steps built in stages.



3. Transamerica Pyramid

Location: San Francisco, California, United States
Height: 260 metres (853 feet)
Estimated age: 37 years
Facts: Although not an ancient pyramid, this office building is currently the tallest pyramid in the world.

3. Completing the pyramid

After the core of the pyramid was completed, workers filled in the corners that had previously held cranes. Egyptologist Bob Brier found one area on the pyramid's exterior that may be evidence of one of these corners.

4. A smooth surface

Originally the exterior of the pyramid was also covered with casing stones, which gave it a smooth appearance. Today only the core inner structure is visible.

The Wright Flyer

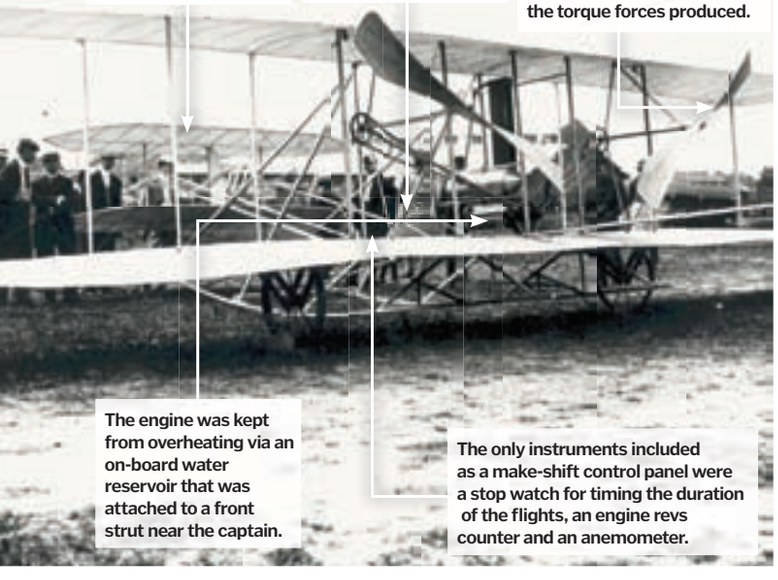
The Wright brothers' first powered plane was called the Wright Flyer, we find out how it worked

On 17 December 1903 in Kitty Hawk, North Carolina, the Wright Brothers – Orville and Wilbur – alternately flew their 'Flyer' four times, the longest of which covered 852 feet (259 metres) lasting just a second short of a minute. These daring feats on that fateful day meant they became the first people to successfully invent, build and pilot a heavier than air power-driven machine.

The main breakthrough of the Flyer is cited as the aviators' invention of three-axis control, which enabled the pilot to steer effectively and maintain its equilibrium. The direction of the plane was controlled using a unique hip cradle invention which was operated by the pilot sliding his hips from side to side and lean into the turn. This was connected to the plane's wingtips with wires, forcing the wings to twist, and by extension – roll. To assist these turns, the American inventors pioneered the idea of wing warping – the twisting of the wing – resulting in one end of the wing having more lift than the other. A rudder was also connected and controlled by the cradle.

The plane could be pulled up and down by a pull system which was operated by the pilot's left hand. Today the elevator is traditionally located in the tail section, but in 1903 the Wrights decided to place it in the front of the plane as they assumed it would prevent the plane from nose-diving if the plane stalled. The aircraft was powdered by a 12 horsepower four-cylinder gas engine, constructed with the help of machinist Charlie Taylor and weighed 77kg. The solitary control bestowed upon the engine was a fuel valve that was connected to a stick and once the engine was active this valve was used to cut the power.

To this day both states of Ohio and North Carolina take credit for the Wright brothers and their extraordinary inventions. Ohio because Dayton was the base for the pair's development and construction of their designs and North Carolina because Kitty Hawk was the site of this first world-changing flight.




The V-2 rocket was one of the Nazi's most destructive weapons

V-2 rocket

How Hitler's V-2 rocket worked and how it could have won the war

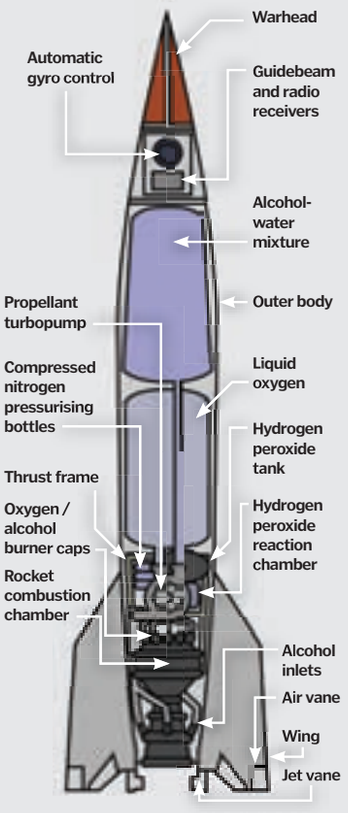
The V-2, short for Vergeltungswaffe-2 and also known as the A-4, was the world's first ballistic missile and was created by the Nazi military during World War II and has inspired many generations of replicas still in production today.

The rocket was designed for sub-orbital space flight, therefore launched from earth and upon reaching an altitude of around 80km fell back to earth exploding upon impact. The V-2 programme is suggested to have been the single most expensive development project of the Third Reich. It claimed the lives of 20,000 inmates of the labour camp Mittelbau-Dora, who died constructing over 6,000 replicas of the device and is thought to be the only weapon system of its kind to have caused more deaths during its production than the actual usage.

The first successful launch occurred in early October 1942 but wasn't fully employed in the war effort until September 1944 where it was used to first bomb Paris, and two days later London. During its reign of limited service by the Nazis, over 3,000 clones were launched resulting in the deaths of 7,250 civilians and military personnel. London received the second highest number of attacks (Antwerp being the most common target) killing 2,752 civilians, statistically two people per V-2 rocket.

However, while in the beginning many were misdirected and exploded harmlessly, improvements in accuracy increased greatly during its development, resulting in missiles claiming hundreds of lives at a time. Anti-aircraft and gunfire were no match for the V-2's speed and trajectory, dropping at four times the speed of sound. It is suggested that had the deployment of the V-2 rocket happened a few years earlier, Hitler could have won the war.

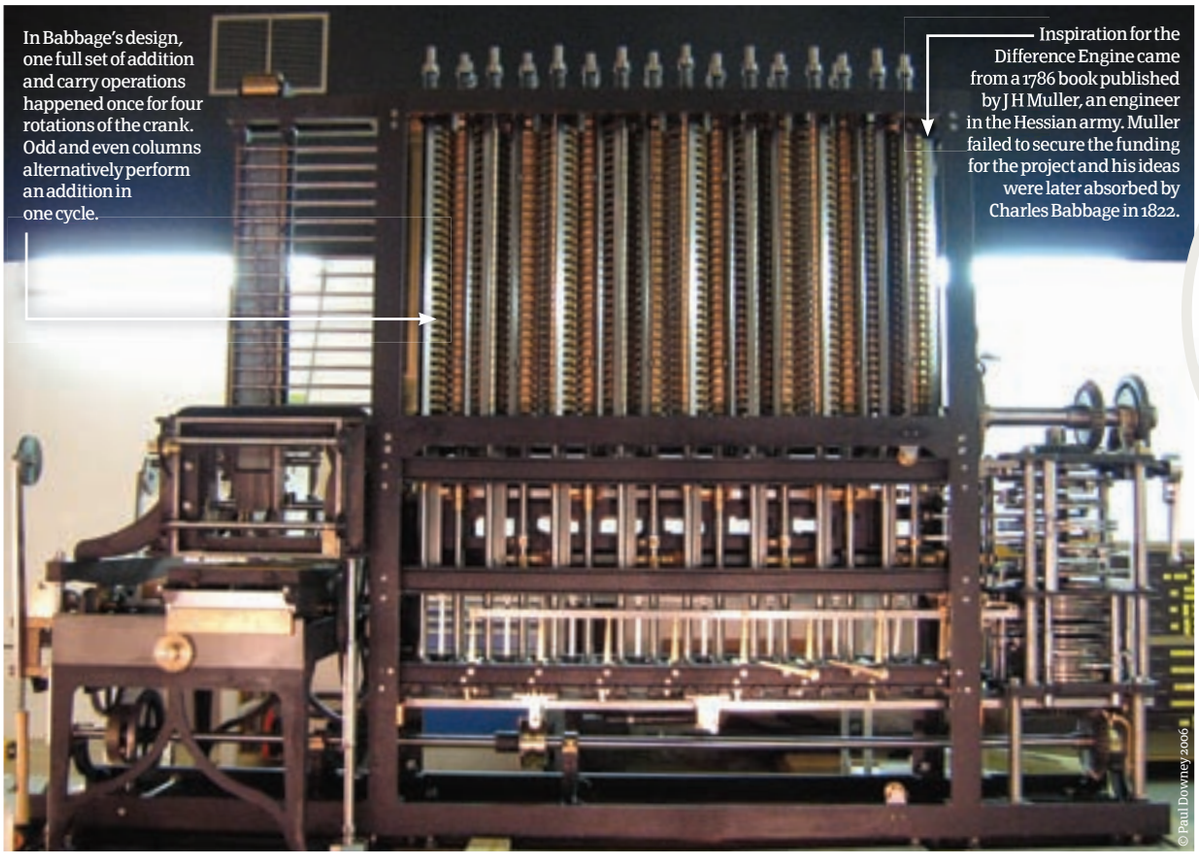
After the war ended, and in the escalation of the Cold War, the US and USSR began to retrieve as many V-2 rockets and staff as possible. In fact Dr Walter Dornberger the leader of Germany's V-2 rocket programme, was enlisted by the US Air Force to develop guided missiles.



DID YOU KNOW?

The first printer...

The London Science Museum completed Babbage's designs for the Difference Engine No.2 in 1991. In 2000 the engineers constructed and added the printer that was invented to work in tandem with the machine.



The first computer

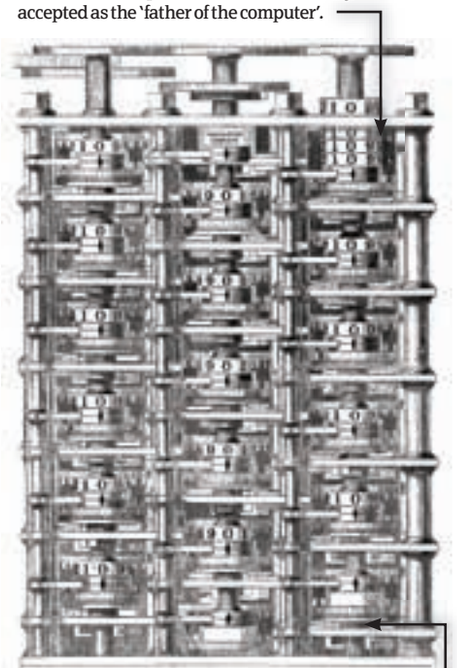
Charles Babbage invented the first computer, called the Difference Engine. How on earth did it work?

The Difference Engine is the first automatic, mechanical calculator designed by British mathematician Charles Babbage, who proposed its construction in 1822 to the Royal Astronomical Society. He suggested the machine would employ the decimal number system and would be powered by turning a handle, as a method to calculate mathematical tables mechanically, therefore removing the high rate of human error.

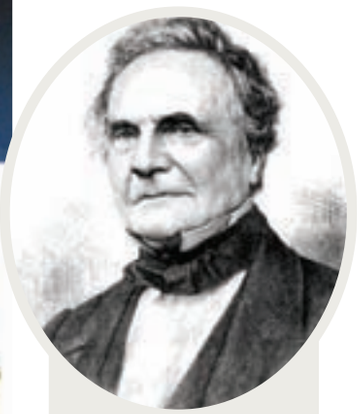
At first Babbage received financial backing from the British Government, but this was later pulled when no apparent progress had been made on constructing the device. The inventor went on to design a more general analytical engine and then later in 1847 an improved engine design – the Difference Engine No. 2.

From 1989 to 1991, using Babbage's original plans of this second version, the London Science Museum constructed Babbage's envisaged machine. Faithful to the original designs the machine consists of over 8,000 parts, weighs five tons and measures 11 feet in length. In 2000 the printer which he plotted to accompany the engine was added and together performed as the inventor had intended over a century before. The completion of the machine ended a long-standing debate as to whether Babbage's designs would've worked.

Babbage designed the first mechanical computer – the Difference Engine – that eventually led to the invention of the first mechanical computer and as such is widely accepted as the 'father of the computer'.



Despite the fact the machine looks archaic by modern standards the basic architecture is similar to the contemporary computer. The data and program memory are separated, operation was instruction ruled, the control unit could make conditional jumps and the engine had a separate input/output unit.



Charles Babbage

Born in London in 1791, Charles Babbage was a mathematician, philosopher, inventor and mechanical engineer. He was formerly tutored as a child in Devon and Middlesex, and in 1810 he attended Trinity College where he claimed to be disappointed in the mathematical education available. Teaming up with John Herschel and George Peacock, among others, Babbage and company formed the Analytical Society in 1812. In 1814 he married Georgiana Whitmore and moved to Dudmaston Hall in Shropshire where Babbage engineered the central heating system. The couple had eight children, three of which survived to adulthood. In 1827 Charles' wife, father and at least one son died, it was these sad events which caused the inventor to suffer a mental breakdown, delaying the construction of many of his machines. He died aged 79, it is thought of 'renal inadequacy, secondary to cystitis'. Half of his brain is preserved in the Hunterian Museum in the Royal College of Surgeons, London.

BRAIN DUMP

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HOW IT WORKS EXPERTS

How It Works is proud to welcome the curators and explainers from the National Science Museum to the Braindump panel

Alison Boyle
Curator of Astronomy

Alison Boyle graduated in Experimental Physics from the National Univerisity of Ireland, Galway, in 1998. She completed a European Master's Degree in Astronomy at the Universidade do Porto, Portugal, and the University of Oxford. She joined the Science Museum in 2001 as part of the Antenna Science News team.

Rob Skitmore
Assistant Curator of Technology

Rob Skitmore is Assistant Curator of Technology at the Science Museum. With a background in IT, Rob has worked on exhibitions spanning diverse topics in the history of technology including time measurement, genetic modification and post-war British technology. Rob's interests lie in gadgets, robotics and computer technology

Phil Raby
Editor in Chief, Total 911

Editor in Chief of **Total 911** magazine, Phil's area of speciality is cars, especially Porsches, although he appreciates all forms of engineering and loves to take things to bits. He's a self-confessed gadget junkie and is never far from his iPhone.

Picture courtesy of NASA

"What's the next nearest galaxy to ours and what's the chance of there being another Earth in it?"

Donna Richards, email

■ The next nearest galaxy is actually inside our own galaxy. It's called the Canis Major Dwarf galaxy and eventually it will be completely absorbed by our Milky Way galaxy. It contains around a billion stars, compared to the 200 billion in the Milky Way. The nearest big galaxy to ours is Andromeda, around 2 million light years away.

Astronomers have discovered more than 400 planets around stars other than the Sun, but most of these resemble gas giants like Jupiter rather than our rocky Earth. New telescopes have revealed a handful of more Earth-like planets but it's still very hard to detect a small planet close to a star.

All of the extrasolar planets so far confirmed have been in the Milky Way, as it's very difficult to spot something as small as a planet in another galaxy. But theorists reckon that there could be billions of Earth-like planets in our own galaxy, and a similar number in others. So somewhere out there, ET may be waiting...

Alison Boyle

"Astronomers have discovered more than 400 planets around stars other than the Sun"

If the universe is expanding, that suggests it must have a finite border – what's beyond that?

James Matthews, email

■ It's hard to imagine, but the universe doesn't have an edge in the normal sense. The Big Bang theory, the most widely accepted description of the universe, states that the universe is expanding from a very hot and dense initial state – but it's not expanding into anything else, as space itself didn't exist before the Big Bang.

Some astronomers think the universe


Picture courtesy of Toyota

"Are hybrid cars really environmentally friendly?"

Paul Tyler, email

It depends on how they are used. They're great for city drivers, when a hybrid can rely almost fully on its electric motor, which is quiet, doesn't create any emissions, will turn off completely when the car is stationary and, crucially, gives superb fuel economy.

Get on the open road, though, and the hybrid will have to fall back onto its petrol engine, because the electric motor simply doesn't have the power to drive the car at higher speeds, nor the energy to run for long distances. In such cases, then, the hybrid will act just like a comparable conventional petrol-powered car, and offer similar fuel economy and the same emissions.

Indeed, some small modern diesel-engined cars produce lower emissions and give better economy than hybrids when driven in this way. They are usually cheaper to buy, too.

You should also take into account that the manufacturing of batteries for a hybrid car requires a lot of energy. And then, after they have reached the end of their life (which may be after just two years), more energy is required to decommission and recycle them. This and the development impact actually makes hybrid cars less environmentally friendly than the manufacturers would really like you to believe.

Phil Raby

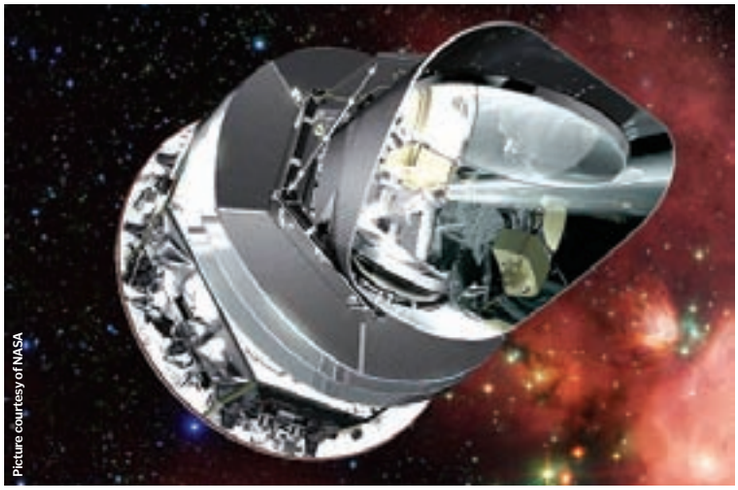
How do barcodes work?

Patrick Harper, email

Barcodes are a machine-readable way of writing letters and numbers. A laser is shone onto the barcode and the reflected light can be interpreted by the barcode reader.

There are many types of barcodes, but the ones most commonly found in supermarkets use a row of lines of different widths. The different widths represent different numbers. In the UK many items are coded with a GTIN – Global Trade Item Number. This allows the manufacturer to print the barcode on the packages which can then be read in many different shops. The numbers are unique to that item. The barcode only has a number, but no product information. That is held in a database which the retailer can access at the point of sale. It also means that shops can set their own prices and change them easily without re-labeling every item on the shelves.

Rob Skitmore


Picture courtesy of NASA

might be infinite. As to what shape it is, it could be flat, behaving like the geometry we are familiar with from school. Or it might somehow curve back on itself, requiring a more complex geometry to describe it.

A spacecraft called Planck is currently studying the cosmic microwave background. This is remnant radiation from the Big Bang that permeates the whole universe. Small fluctuations in the cosmic microwave background provide clues as to how the universe has developed into what we see today, and Planck's results should help mathematicians refine their models of the universe's shape. However, there is a limit to the observable universe – no matter how good our technology gets, we will only ever be able to observe areas from which light has had time to reach us since the universe started expanding. The boundary of this area expands as the universe does.

Alison Boyle

Just what is 3G?

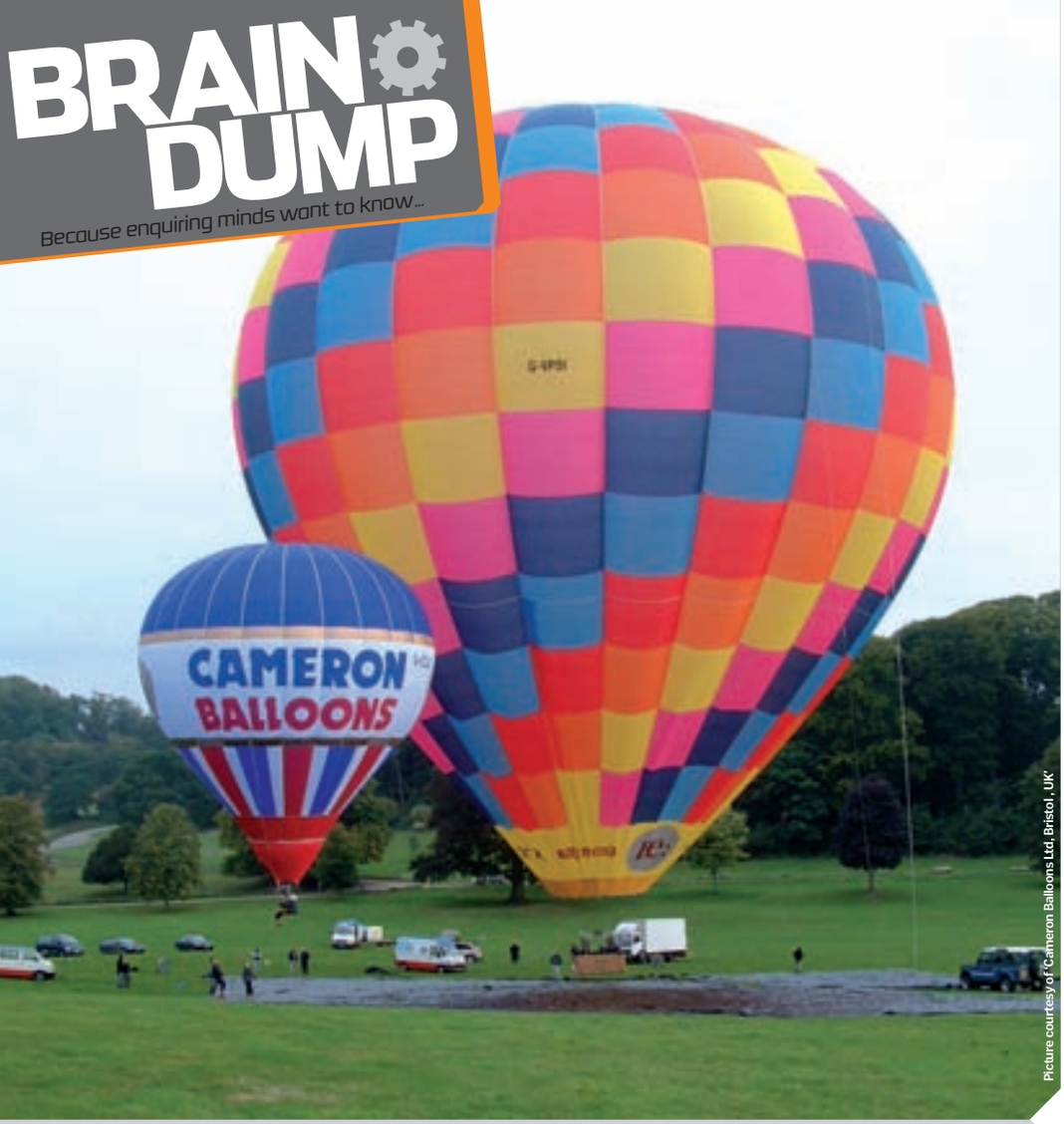
Scott Gregory, email

3G or 3rd Generation is a set of standards for mobile phones and other mobile devices. Services include mobile voice telephone, video calls, and wireless data connections. 3G allows simultaneous use of speech and data services and higher data rates up to 14.0 Mbit/s downloads on some systems. 3G networks offer users more advanced services than numerous previous phone standards.

Rob Skitmore

BRAIN DUMP

Because enquiring minds want to know...



Picture courtesy of 'Cameron Balloons Ltd, Bristol , UK'

"What is the highest a hot air balloon has ever gone?"

Duncan Silsow, email

The record for a hot air balloon is 21,027 metres. This was set in Bombay in 2005 by Indian businessman Vijaypat Singhania, who was 67 years old, in a Cameron Z-type balloon (pictured above). In 1960, US Air Force Captain Joseph Kittinger reached a height of 31,090 metres but that was in a helium balloon. Oh, and he then jumped out and parachuted back to earth, therefore breaking another record!

Phil Raby

Why don't forklift trucks tip over?

Sue Daniels, email

Unfortunately they do. Used mainly in warehouses to lift and move heavy loads, forklifts are very dangerous; every year there are over 8,000 accidents involving them. The average weight of a forklift is about three times that of an average car, and this weight is mainly distributed at the rear to counterbalance the load on the forks at the front. The front wheels, meanwhile, act as a fulcrum.

How It Works

FROM THE FORUM

*Every month we'll feature a reader's question and a reader's answer from our forum at **www.howitworksdaily.com/forum***

What exactly is Britain's 'unwritten constitution'

We all know about the American constitution and the rights and protections it gives to American citizens, but I've heard Britain has historically had an 'unwritten constitution'. What exactly is that, how did it come to be and what rights does it give us?

SHB, forum user

For a very brief overview, Britain's constitution is exactly that, unwritten or uncodified.

The difference between, say, America's constitution and Britain's is that the latter evolved organically over time, rather than through a sudden change such as the massive social upheaval caused by revolution or civil war, as is the case with the former. Over time, different components of the law contributed different aspects to the country's overall legal and socio-political framework, resulting in legal measures being drawn from a number of different areas.

The primary contributors to the UK's uncodified constitution are:

- **Parliamentary sovereignty** – the idea that as the people's representative body, statutes passed by Parliament are the supreme source of law in the country.
- **Government and Parliament** – the idea that the executive is drawn from the legislature, and therefore by the will of the people, as the separation of powers is not as distinct in the UK as it is in other Western democracies such as the USA.
- **Constitutional monarchy** – the idea that the Queen reigns, but does not rule, however her actions directly influence the political course of the country by her (largely ceremonial) role of asking a party to form the government.

However, Parliamentary sovereignty is no longer as applicable as it once was due to Britain's membership in the European Union, which automatically means that any laws passed in Brussels immediately supersede conflicting laws passed domestically.

Sources of the British 'constitution' include Acts Of Parliament, common law, Royal Prerogative, Treaties, EU law, conventions and works of authority. Benefits of an organic or uncodified constitution include its constant adaptability and rapid assimilation of events, expanding the law to accommodate them. Drawbacks include no codified form of human or civil rights in one document, less protection against the encroachment of dictatorship, and instability caused by conflicting sources and the introduction of new ones.

SFNJim, forum user

How do painkillers like paracetamol cure headaches?

Ben Danks, email

■ We all feel pain differently, depending on the severity of the injury or ache, as well as our health and our pain threshold. When you are in pain, nerve endings transmit the pain signal to the brain via the spinal cord. The brain then interprets the level of pain.

There are two key types of painkillers that are commonly used. The first include ibuprofen and paracetamol, which block the body's 'prostaglandins' (chemicals that produce swelling and pain) at the source of the pain, reducing swelling in the area and reducing the intensity of pain. These 'aspirin medicines' are used frequently for mild to moderate pain, but they can only work up to a certain intensity of pain. There are different types of painkillers within this group, such as anti-inflammatory medicines, like ibuprofen, which are commonly used to treat arthritis, sprains and strains. Aspirin is used to help lower the risk of blood clots when used in a low dosage, as they thin the blood. Paracetamol is an analgesic, which is used for reducing pain and lowering a temperature.

The second type of painkillers include morphine and codeine (narcotic medicines), which block the path of pain messages in the spinal cord and the brain. This is for much more severe pain.

As both types of painkillers use slightly different methods to treat pain, they can be combined, such as in co-codamol, which blends codeine and paracetamol.

How It Works

"Do fish really have a three-second memory, and how do we know this?"

Jayne McGinty

■ This is a myth and there have been various studies disproving the commonly held belief. In January 2009, researchers from the Technion Institute of Technology in Israel taught fish to respond to a sound that meant feeding time in captivity. The fish remembered the sound months later having been returned to the wild, returning to a certain spot for feeding.

How It Works

How do microwaves cook food?

Chris Viegh

■ Microwaves are a form of electromagnetic wave like any other radio wave. Microwave ovens heat the water molecules inside foods, which gives off heat energy that can be used by other molecules in the food to warm them up as well. This is why pasta and rice often need water added in order to heat them up.

How It Works

Why do bats insist on sleeping upside down?

Chris Fielding

■ This is partly because they can't grip with their 'hands' so use their feet instead, but the feet wouldn't support their weight if they stood on them. Also, bats can't launch themselves from the ground to take off like birds do, so from a hanging position they can use gravity to their advantage to get airborne, as well as being protected from predators.

How It Works

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

DVDs/Blu-ray • Books • Gadgets

The Knowledge Book

Price: £19.99

ISBN: 978-1-4262-0124-0

This succinct hardback volume summaries the culmination of several millennia of knowledge with clear, informative illustration and text. It's no good for London cab drivers looking for a short-cut, but it's obvious living room bookcase fodder and it doubles as a perfect GCSE companion too.

Verdict: ✿✿✿

History

Price: £30

ISBN: 978-1-4053-1809-9

As if it wasn't enough for us to see the endorsement of uber-genius Adam Hart-Davis on the cover, this "definitive visual guide" to 6,500 years of human history is indeed peppered with a visual buffet of photography and fact, from bite-size boxouts of information to entire spreads devoted to pivotal events in history.

Verdict: ✿✿✿✿

200x zoom

Fancy getting some Attenborough out of your ant farm?

Discovery Veho USB Microscope

Price: £69.95

Get it from: www.firebox.com

THESE DAYS WE take photos of everything at any opportunity, so it was only a matter of time before someone attached a microscope to a computer. What we would have given for this when we were kids...

The Discovery Veho VMS-004 combines a simple microscope with a 20x to 400x magnification, a light and a two megapixel camera. It interfaces and is powered by your PC via any free USB port, coupled with drivers and a simple piece of software called Microcapture, which is where all the magic happens. The microscope will take high-resolution photographs (up to 1600x1200) of anything that you place within a couple of centimetres of the lens. All you have to do is adjust the wheel on the top to bring the subject into focus and either click the capture button on the side of the microscope, or on the toolbar of the application window. At higher magnifications though, you'll need a very steady hand to keep the image from wobbling out of focus and sadly the stand is slightly underweight, making it top-heavy.

The Microcapture software is basic but functional and very easy to use, allowing you to take .avi format videos as well as .jpeg images. There's even a simple art kit with which you can frame and decorate photos with a theme or import your own bespoke border.

The implications of the USB Microscope for children's scientific pursuits are broad: school kids will even be able to view microscopic creatures on a PC monitor (or big screen, if your graphics card has TV-out) and video them. But at just under 70 quid, there's undoubtedly scope for the Discovery Veho as a scientific desktop gadget for adults. It's worth noting too, that the ease with which you can take finely detailed close-ups make the Veho ideal for online auctioneers looking for a cheap alternative to buying an expensive camera setup.

Verdict: ✿✿✿✿

Wenger Giant Swiss Army Knife

You call that a knife? This is a knife...

Price: £499.95
Get it from: www.firebox.com
TRULY, THIS IS THE MULTI-TOOL for anyone that stuck a bodykit, spoiler and enormous exhaust on a Corsa, or the person that pumped so much cash into their PC it could run the entire Folding@home project solo. This is a Swiss Army knife that could furnish the needs of an entire company of Swiss army folk if it wasn't for the fact that it's almost totally useless.

We can imagine this product starting life as a concept joke from engineers, one which elicited so many gasps of awe from male Wenger employees that the project was green-lighted. Despite the fact that the Giant Swiss Army Knife incorporates 141 different functions into 87 tools including a laser pointer, golf reamer and cigar cutter, it's so large and unwieldy that it can't possibly be of any practical use. It's the embodiment of inane masculine one-upmanship – and that's the point. But for £500, this tadger-swinging competition you're entering had better be worth winning.
Verdict: ✪✪

Korg Kaossilator

Phat riffs and slammin' beats in a hurry

Price: £149.95
Get it from: www.firebox.com
THE KAOSSILATOR IS an entry-level portable synthesizer and is perfect for the hobbyist and general musical meddling. Featuring 99 different instruments from conventional piano and percussion to 8-bit game sound effects, all of which can be manipulated via the touch screen, the scope for composition is almost infinite.

The Kaosssilator has phono and RCA outputs for recording, but it has no MIDI-out, so unless you're willing to risk a bit of modding you won't be able to synchronise your live equipment around it. But bearing in mind that someone tone deaf and brain-dead can string together a plausible tune from it, it's an especially addictive box of musical tricks.
Verdict: ✪✪✪✪

New Super Mario Bros Wii

Format: Wii
Price: £39.99
Get it from: www.amazon.co.uk
Just in time for Christmas, Nintendo is releasing its much-anticipated co-op platformer *New Super Mario Bros Wii*. Enabling up to four players to enjoy the traditional brand of Mario fun, this will keep the whole family entertained throughout the holidays. Although the single-player experience is a highly polished affair, it's the multiplayer that will come under scrutiny... and the game doesn't disappoint. There are many unique features and some charming gameplay elements, and you can rest assured that, with a focus on social party play, this is the must-have Wii game of the year.
Verdict: ✪✪✪✪✪

Modern Warfare 2

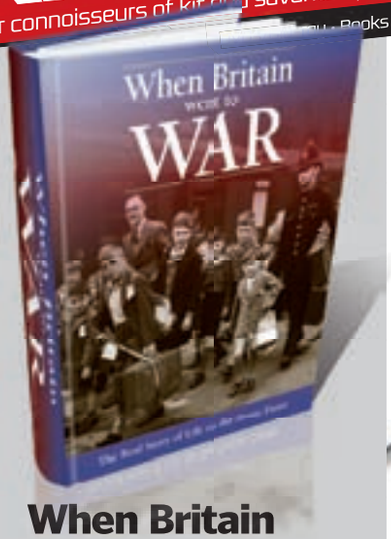
Format: 360/PS3/PC ■ Price: £54.99
Get it from: www.play.com
Activision is publishing several different versions of its highly anticipated first-person shooter. The most notable of which, the Prestige edition, is coupled with a pair of *MW2*-branded night vision goggles... for a prestige price. But don't let those distract you from the real fun here, because developer Infinity Ward has raised the bar again. The realism of the modern battlefield is in sophistication and subterfuge, with *Modern Warfare 2*'s AI proving as slippery as a blood-slick combat knife. With a new two-player co-operative SpecOps mode, there's an enormous amount of gameplay for money here.
Verdict: ✪✪✪✪

EyePet

Format: PS3 ■ Price: £34.99
Get it from: www.game.co.uk
The electronic pet phenomenon that was the Tamagotchi has experienced quite the evolution since those heady glory years in the Nineties. These days you'll find them languishing on handheld consoles or as a part of a larger gaming experience, but occasionally the big boys give the genre a limelight of their own. *EyePet* is a PS3 exclusive that uses the Eye Camera to track your movements in conjunction with a cute character of your own creation. And cute is the buzzword here, because your creature will copy drawings you've held up to the camera into its scrapbook and even bring them to life.
Verdict: ✪✪✪

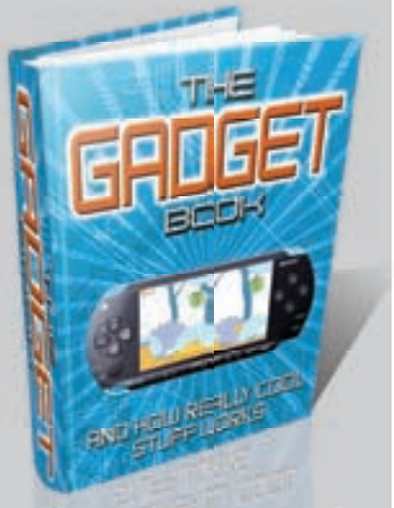
DJ Hero

Format: Xbox 360 ■ Price: £89.99
Get it from: www.hmv.com
Guitars, microphones, entire four-piece bands and now DJ mixing decks. Has the rhythm-action genre taken a ludicrous leap too far this time? Absolutely not: *DJ Hero* is no novelty tie-in to the legendary *Guitar Hero* franchise. It comes with a rotating turntable controller and mixing deck, complete with cross-fader, sample buttons and effects dial, with which 80 exclusive mixes by artists such as DJ Shadow can be fused into an original track. Players have to match their track to a prescribed beat, but unlike *Guitar Hero, DJ Hero* leaves room for some creative expression here too.
Verdict: ✪✪✪✪✪



When Britain Went To War

Price: £20.00
ISBN: 978-1-844258-42-0
At last, a chronological volume that makes up for the deficit of books based on British life during World War II. Focusing on rationing, crime, fashion and entertainment for those who were left at home, it's a fascinating insight into British stoicism despite the adversity posed by the 1939-1945 period.
Verdict: ✪✪✪✪✪



The Gadget Book

Price: £14.99
ISBN: 978-1405341615
Now, this is a publication after our own heart. *The Gadget Book: And How Really Cool Stuff Works* is now out in paperback, and is an essential read for eager minds. As well as the beautiful lenticular cover illustration, this book is full of juicy facts and breathtaking imagery. Although fairly light on text, it offers a basic insight to many subjects including how rollercoasters provide thrills, what keeps gliders in the air, and the security features of modern money.
Verdict: ✪✪✪

Altec Lansing Expressionist Ultra

Chest-kicking sound… at a chest-beating price?

Price: £179.99
Get it from: www.play.com
PERHAPS IT'S BECAUSE we failed art at GCSE, but at a glance we were slightly confused, rather than stratospherically impressed, by Altec Lansing's latest 2.1 speaker solution. The satellite speakers with their simplistic smoked plastic surround look as if they're part of a DIY speaker kit and as beefy as the 165mm woofer is, it doesn't need to be half that size.

Fortunately the Expressionist Ultra does produce the kind of dirty bass sound that anyone sitting less than 20 feet away from would enjoy. It's a 200 watt system, which is punchy enough to disturb the neighbours at three quarters max volume without offending their ears with noise distortion. But for nearly a pound per watt we'd expect a few more features, like a phono input, a more conventional volume control than the ostentatious dial and we don't think a mute button is too much to ask for the money either.
Verdict: ✪✪✪

Swann PenCam

Spy fanatics and undercover journalists could be onto something here

Price: £80
Get it from: www.swannsecurity.com
THE IDEA OF a Bond-style spy pen that takes snapshots and audio-accompanied video ought to get most guys scrabbling for their wallets at £80 a pop. Pitched as an executive toy or gadgeteer's gift, the Swann PenCam looks just like an ordinary pen but incorporates a near-invisible pinhole camera that is activated by depressing a secreted button. It unscrews halfway to reveal a USB device that holds up to a respectable 2GB of photos and footage, with enough life in the USB-rechargeable lithium-ion battery to last up to 90 minutes.

For a multimedia device of this size and pricing, you can't expect camera or even camera phone quality. Photos are relatively low resolution and the lack of any image stabilisation technology means that unless the PenCam is absolutely still, video will blur at the slightest jolt. The Swann PenCam's novelty value for money can't be contested though and for a PI undercover, its audio capacity could be compelling enough.
Verdict: ✪✪✪

Sony Handycam HDR-TG3E

Great home videos come in small, tough and lightweight packages

Put your compact camera away, this captures stills at four megapixels and dual-records at 2.3 too

Price: £509
Get it from: www.sony.co.uk
MANUFACTURERS SOMETIMES find it all too easy to use the excuse that quality has been compromised on for price and portability, but here it hasn't.

We tried and failed to find a flaw with Sony's new handheld camcorder, because while the Handycam HDR-TG3E isn't within range of everyone's pocket, its superior technology and portability is worth twice the price. Its 1920x1080i full HD capacity isn't basic functionality by anyone's standard: just hook a full resolution recording up to a HDTV for picture quality that does dimples and blemishes proud on family video, especially coupled with the Handycam's 10x optical and an amazing 120x digital zoom.

You won't find anything current to match it in terms of lightweight durability either, with a scratch-resistant titanium body around a compact pocket-size frame. Furnished with a lovely 2.7-inch LCD screen and award-winning design features, it's a perfect solution for amateur filmmakers.

Verdict: ✪✪✪✪✪

Brennan JB7

Store up to 5,000 CDs on this revolutionary hi-fi from Brennan

Price: from £329
Get it from: www.brennan.co.uk/shop
FOR THE PERSON who really loves their music, this piece of kit is a real treat. Simple, back-to-basics design belies the incredible tech inside this powerful little hi-fi. Available in 60/160/320GB versions, the JB7 enables you to manage your entire music collection without the need for a PC. You can record from vinyl, CD, cassette, or radio; you can do a text search for tracks and albums using the dinky remote control, and you can load and play MP3s from USBs. There are so many more great aspects to this music management system that we cannot squeeze them into this review, so we recommend you check out the Brennan website for more details.

Verdict: ✪✪✪✪✪

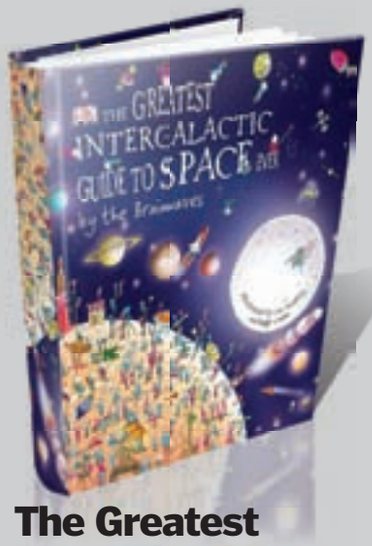
iBand

Impact protection for the mighty iPhone has never come in a more unlikely package

Price: £19.99
Get it from: www.amazon.co.uk
INVENTED BY A snowboarder, d30 is a substance that's quite malleable at low velocities but also absorbs high-impacts. It has a variety of sporting applications, particularly in alpine pursuits, but as a shock-absorbent material in an iPhone case it's of questionable merit.

It's a little fiddly moulding the sticky orange goop into the casing and we have to wonder why we're doing this ourselves when gel packs would suffice. Though the protection it offers is undeniable, shielding the iPhone from forces other sheaths would buckle under, it's messy and it makes volume and power buttons difficult to press despite the tabs.

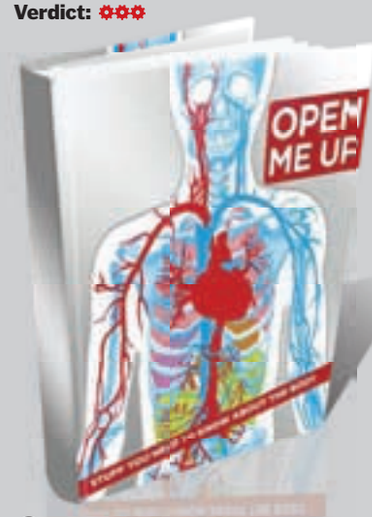
Verdict: ✪✪



The Greatest Intergalactic Guide To Space Ever

Price: £12.99
ISBN: 978-1-40534-616-0
What this children's space encyclopaedia lacks in accessible layout it makes up for in charming illustration and information. It's bursting with bite-sized facts that will appeal to all ages: did you know the universe was once as small as a full stop? That alone should be enough to grab a child's attention.

Verdict: ✪✪✪



Open Me Up

Price: £14.39
ISBN: 978-1-40534-160-8
It covers in detail 'stuff you need to know about the body', and DK meant that in the anthropological as well as biological sense. What the cover line doesn't tell you about is the diverse and accessible way this volume has been designed. Comic-book, encyclopaedia and posters, among other styles, make up this substantial page-turner.

Verdict: ✪✪✪✪✪

GROUP TEST

Pointing and shooting takes on a whole new meaning in our cutting-edge compact group test...

Touch screen digital cameras

HOW IT WORKS GROUP TEST WINNER

1 Canon IXUS 200 IS

Price: £239
Get it from:
www.crazycameras.co.uk

As the most expensive device in our touch screen camera test, it's no surprise that the IXUS 200 IS was designed as one of the first of its kind to incorporate this new LCD technology. Canon has slashed the price on this model quite recently, cutting back on some touch-screen features and instead incorporating buttons and a dial for at least a range of the available functions. Plus we're quite fond of the blue casing. Other features that are on offer include an ultra-wide angle and a 24mm lens with a 5x optical zoom. Coupled with a 12.1 megapixel sensor, this device is amply equipped to do the job for an amateur photographer.

Verdict: ✿✿✿

2 Samsung ST550

Price: £204.99
Get it from:
www.camerabox.co.uk

You know the photo: a grinning mugshot with outstretched hand that disappears at the wrist somewhere to one side. Everyone has taken their own snap with a digital camera at some point, so Samsung is offering a 12 megapixel sensor camera with a three-inch touch screen LCD, with which you can control almost every function of the camera. That's pretty mundane compared to its main feature though, which is a hidden 1.5-inch screen in the front so you can view your self portrait while you take it. And if you thought that was vain, face recognition technology means it won't even take your picture until you actually smile.

Verdict: ✿✿✿✿✿

3 Sony Cyber-shot TX1

Price: £229.95
Get it from:
www.simplyelectronics.net

This touch-screen solution from Sony won't tempt those with an appetite for gadgetry away from the likes of Samsung's ST550, but what it lacks in cutting-edge gimmicks, it more than makes up for in high-tech features. A 10.2 megapixel sensor is a little lower than its contemporaries, but typical to the Cyber-shot series, a Carl Zeiss Vario-Tessa lens technology allows for extreme close-ups, while the Exmor R CMOS sensor is more effective at gathering light for clearer stills even in murky low light scenarios. Again, the three-inch touch screen allows almost total control over shooting, for a remarkably sleek camera more compact than most.

Verdict: ✿✿✿✿

4 Panasonic Lumix DMC-FX550

Price: £184.99
Get it from:
www.camerabox.co.uk

Current compact camera chic dictates that most manufacturers opt for a sleek and curvy chassis. Panasonic has bucked the trend by creating the DeLorean equivalent, ironically naming this boxy retro Lumix the DMC-FX550. Panasonic has gone for the three-inch LCD/button hybrid rather than the full electronic control that other touch screen compacts boast. Like its competition, it offers 5x optical zoom and image stabilisation, plus a number of standout studio features that allow you to manipulate images with text and basic drawing on-screen. It might look dated, but the DMC-FX550 hides a surprising amount of innovative technology within its retro exterior.

Verdict: ✿✿✿

HOW IT WORKS

INBOX

Feed your mind. Speak your mind

Get in touch!

If you've enjoyed this issue of **How It Works** magazine, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. We'd love to hear from you. There are several easy ways to get in touch...

Forum

Those who like to spark debate and enjoy healthy discussions among like-minded individuals can visit **www.howitworksdaily.com/forum** and put their questions to the **How It Works** experts.

Email

If you'd like to contact us directly and perhaps even see your letter featured right here then get online and tell us what you think. Just email **howitworks@imagine-publishing.co.uk** to have your say.

Snail mail

Yes, we even welcome the good old pen-and-paper method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ.

Letter Of The Month

A force to be reckoned with

■ Thank you for publishing such a fantastic magazine. I completely agree with the editor's comment on page three that there is a huge audience wanting info-tainment. I am a physics teacher and this is exactly the sort of magazine that will inspire our students. So thank you.

However, I have a comment regarding the Q&A section: the answer on Niagara Falls is misleading, which makes it tough to explain to the students.

The use of F=ma in the context given is wrong, using a as 9.81m/s/s, the question is asking about force no doubt applied by the falling water. So it has to be F = rate of change of momentum. This depends on how fast the water is falling at the time that it hits the bottom of the waterfall, and a judgement on how long it takes to lose its vertical velocity. Obviously it depends on the height of the waterfall – and given that you can easily use v squared = u squared + 2as etc.

Paul Harvey, email

HIW: Your email is much appreciated, Paul, and we thank you for taking the time to explain why you think our expert's response to the question might confuse readers. We agree that How It Works is a great source of knowledge for students and eager minds everywhere so it is essential that we ensure the accuracy of everything we print.

Looking good

■ I just picked up **How It Works** today, and I have to say it's a really interesting read. The way the features are presented is so exciting and easy to understand, especially the one on the Eurofighter Tycoon. I will definitely look out for the next issue, if only to find out what the picture on the Next Month page is.

Sam Peel, email

HIW: Thanks for your letter, Sam, we do indeed try to make the magazine accessible and educational, as well as using the most eye-catching imagery we can lay our hands on. In fact, if you turn to the feature on the Z machine on page 62, you'll find out the truth behind last month's incredible picture.

"I am a physics teacher and this is exactly the sort of magazine that will inspire our students"

Eye on the world

■ The best part of the magazine, for me, is the section with all the big pictures – Global Eye. The photos across those pages are simply amazing. I think you could make a whole magazine based purely on cool pictures with snippets of interesting information. It's so easy to pick up and flick through. Please can you make this section longer?

Carly Richards, email

HIW: The Global Eye showcase is certainly a very popular section, and a great way to ease readers into the magazine. However, while people do enjoy the immediacy of flicking through and spotting an incredible piece of photography and soaking up the juicy details about that image, many more are also thirsty for really in-depth articles about their favourite subjects and topics they've little knowledge about. It's about maintaining a balance.

Praise from the Hart-Davis!

I was impressed to find How It Works on sale in my little local supermarket, and even more impressed when I looked inside. Wow. What a terrific publication. It looks really good, and if you can keep up that standard you will surely make the magazine a success. General production standards are high, and five minutes' reading suggests the science is good and solid, which is really important. You seem to have covered most of the science and technology in this first issue, and I don't see any obvious gaps. I notice that three of your five named writers are American; is the magazine published in the US too? Congratulations on a great magazine.
Adam Hart-Davis, email

HIW: It's a real privilege to have the backing of such an esteemed follower of the world of science and wonder, Adam, so thank you very much for your email. In answer to your question: the magazine will go on sale in the States at the end of November in both Barnes & Noble and Borders.

Bearded beauties

I really enjoyed the first issue of How It Works. It's not usually my type of mag, but I couldn't put it down until I'd read the whole thing. I just can't wait for the next issue, so hurry up. By the way who is that gorgeous-looking guy with the beard in the picture on the homepage? Is he single?
Rabbit, forum

HIW: We're delighted that you enjoyed our launch issue, Rabbit. We've had a lot of very positive feedback so far and the support we've had from readers has been fantastic, so thanks for all the kind words of encouragement. With regard to setting you up with the bearded member of the HIW team, there are no less than three hirsute heroes in that photo and we couldn't possibly comment on which is the most "gorgeous-looking". Still, if you keep your eyes peeled, who knows, perhaps one day we'll reveal their identity in the mag. Maybe.

Can't get enough of How It Works?

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HOW IT WORKS

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Cover image
iStockphoto

Photography
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Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

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Distributed by Seymour Distribution, 2 East Poultry Avenue, London, EC1A 9PT ☎ 0207 429 4000

ISSN 2041-7322

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